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SPECIAL ASPECTS OF ENVIRONMENT
RESULTING FROM VARIOUS KINDS
OF NUCLEAR WARS

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PREFACE

This report is the work of many people. It was guided and supervised throughout by William M. Brown, Director of Civil Defense Studies at the Hudson Institute. Dr. Brown also made numerous valuable editorial and substantive comments, supplied data or sources of information in many cases, and contributed largely to the structural organization of the report. Much data, including Annex D of Chapter IV in its entirety, was also supplied by Cresson Kearny, as a result of many personal interviews with experts in various fields; he also contributed worthwhile suggestions in an editorial capacity.

Others who did much of the digging for data were Edward Friedman (consultant), Althea Harris (research aide) and Corinne Enders (part-time research assistant). Jean Ingersoll, of the research staff, carried out an independent study under this contract, the results of which are reported in Appendices II and III of this report (bound separately).

Since the draft version of this report, which was issued on March 15, 1963, we have had the benefit of a number of helpful comments and criticisms which resulted in corrections and changes. We particularly wish to thank G. Higgins and J. Minkler of Lawrence Radiation Laboratory (Livermore), D. Grosch of North Carolina State College, T. Stonier of Manhattan College, and A. Sparrow and G. Woodwell of Brookhaven National Laboratory. However, any errors or omissions which may still remain cannot be attributed to these individuals.

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CHAPTER I

CONTEXT OF THE STUDY

This chapter will present background material for succeeding chapters. The first section presents the organizational scheme of the report as a whole, as it arises naturally from various ecological concepts. It also gives necessary definitions and notes limitations imposed by the nature of the subject matter.

The second section discusses the range of possible nuclear attacks on the United States, and relates some of the possibilities to various current strategic doctrines. The principal objective of the section is to gain some insight on the extent to which detailed assumptions regarding attack parameters (e.g. targeting, airburst vs. groundburst, season of the year or time of day, fision-fusion ratios, megatonnage, etc.) constitute useful input data for the study at hand.

Sections §3 and §4 present some of the existing data on biological consequences of radioactivity, namely radiosensitivities of various plants and animals and cycling of nuclides in certain food chains. Information which has been adequately summarized elsewhere, such as somatic effects on humans, and radioactive contamination of human food supplies, is referenced.

§I Organization and Methodology

The study of the interrelationships between members of a biotic community is called ecology, and the community itself is usually referred to as an ecosystem. Since ecology is a relatively undeveloped branch of the biological sciences it is for the most part descriptive rather than analytic. A typical object for an ecological study would be a sand dune, a fresh water pond, or a coral atoll. Such ecosystems are characterized by three things. First, they are relatively simple. Second, they are relatively isolated from contact with the outside world. And third, they are usually in an approximate steady-state or equilibrium.

We are concerned in the following with the effects which a thermonuclear attack on the United States might have on the biological environment insofar as it affects humans. This aspect of the environment might be called the "human ecosystem." As it exists now in its equilibrium state, so to speak, this ecosystem is essentially both simple and isolated. It is simple because so great is the dominance of man over his natural environment that relatively few species, compared to the total numbers, interact strongly with the human population. (We only assert this for North America. It is not necessarily true for example in the jungles of the Congo.) The human ecosystem in North

America is comparatively isolated because of the natural ocean boundaries as well as the artificial barriers set up by public health officials and the Department of Agriculture who guard against inadvertent importations of unfamiliar species of insects, fungi, plants, and even microbes.

The North American human ecosystem can be considered as a number of smaller ecosystems based on geography and climate, merging indistinguishably into one another at the edges and also interacting strongly via the agency of human commerce. Basically, the west Texas highlands, Imperial valley of California, the North Dakota wheat lands, the Appalachian forests, the Iowa-Illinois corn belt, the Mississippi delta, and the Florida citrus groves offer quite radically different local environmental conditions. These ought to be recognized and taken into account in the study.

Ecologists commonly consider three basic relationships a given species may have with another, e.g. it may be neutral (0), beneficial (+), or antithetic (-).[1] The inverse relationship between the second species and the first may not be symmetric, e.g. species A may be beneficial to B, but B may be harmful to A. Between any two species there are therefore six* possible combinations of relationships corresponding to the number of combinations of 0, +, and - in pairs. In our discussion of the human ecosystem we will deliberately ignore certain kinds of interactions, namely interactions in which the second species is affected by the human population but is neither beneficial nor antithetic to it in return. This eliminates from

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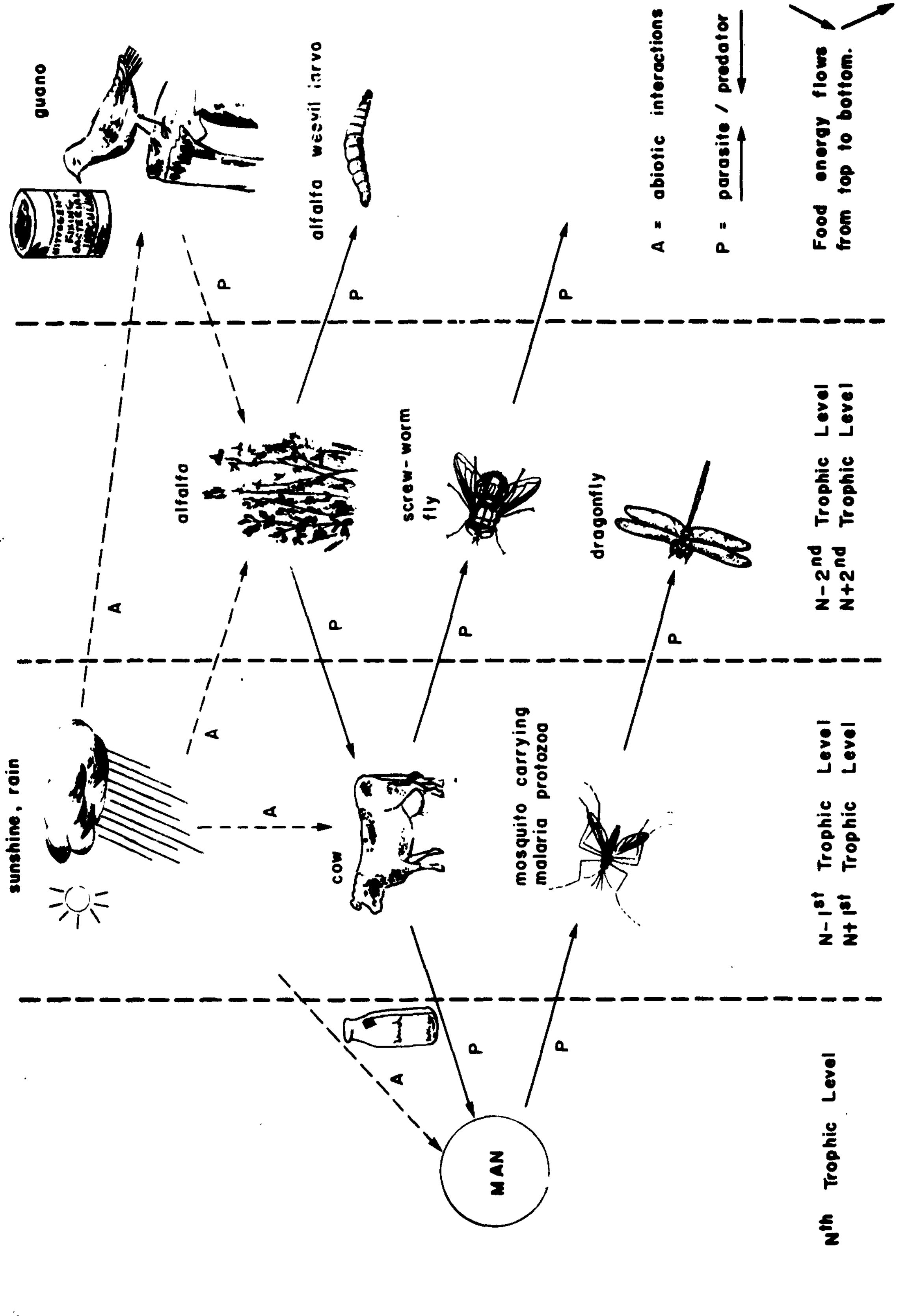
*With the convention that +- and -+ are considered a single classification, etc.

the six possible combinations, all those in which the second of the two symbols is 0 (corresponding to "neutral"). In practice we will also be able to ignore the reverse case where the human population is affected but the other population is not. This is a possible relationship and has indeed been observed between other pairs of species but does not apply to any great extent in the human ecosystem. We are left then with the three combinations as follows: ++ corresponds to "mutualism" or proto-cooperation in which both populations benefit, -- corresponds to competition, and +- corresponds to parasitism or predation. Mutualism and proto-cooperation are often distinguished in that mutualism is obligatory whereas proto-cooperation is not. Parasitism and predation are functionally the same, the principal difference being in terms of the relative size of the parasite or predator and the host or prey in the two cases.

There does not seem to be any case of mutualism between the human species and any other, but proto-cooperation exists with the intestinal bacteria which produce some of the vitamins needed by the human body--replaceable however from other sources if necessary. Competition exists of course between humans and other species for the same food supply. Rats, rabbits, grasshoppers, aphids, and many others could be named. The most important relationships are parasitism and predation which are presumably self-explanatory. These relationships are sufficiently fundamental that they offer the possibility of formulating a framework which is very convenient for the description of an ecosystem, in at least a quasi-analytical way, by introducing the concept of the "food chain."

Every food chain starts with the photosynthesis of inorganic chemicals into protoplasm by plants (which however may range from unicellular algae to giant Sequoia). Plants are called the first trophic level. The second step in the food chain consists of animals feeding on the plants and converting the plant protoplasm into animal protoplasm. To the extent that any animal obtains food directly from plant sources it belongs to the second trophic level. Animals on this level range from small aquatic animals to large herbivorous creatures such as the cow, and also omnivorous animals including man himself. A complex food chain may also include several further levels of carnivores and omnivores. If a complex food chain is represented in diagramatic form, it will consist of a pattern of branches and intersections (see Figure I-1, the Organizational Chart). Each species in an ecosystem is represented by an intersection of several branches which may stand for predator or parasite relationships. Such a graph can be ordered in terms of trophic levels, say from right to left starting from the lowest photosynthetic level. With this orientation, lines converging toward the left represent different food sources for one species while lines diverging toward the left represent different species feeding on a given source. Thus competition for food is represented in this diagram. Food energy flows in the diagram from right to left if no distinction is made between parasite and predator relationships. We have chosen this scheme for Figure I-1 with the further convention that food energy always flows from top to bottom.

FIG. I-1 ORGANIZATION CHART



The organization of this report is derived from Figure I-1. Since photosynthetic organisms (plants) are generally referred to as the first trophic level, we shall hereafter refer to man as the Nth trophic level. The most important ecological interactions affecting man are therefore those between the Nth level and the N-1st level.* These are two general types depending on the direction of flow of food energy, namely energy "sources" and energy "sinks." Energy sources include plants and animals (mostly micro-organisms and insects) which in turn feed on humans. An alternative description in terms of our earlier language would be to say that the former were predator relationships (humans being the predators) and the latter, parasitic relationships, humans being in this case, the prey. A third kind of interaction is represented by dotted lines in Figure I-1. This is essentially an abiotic interaction with natural features of the environment including water, soil, and weather. These factors interact with every trophic level and therefore both directly and indirectly with humans. The three major sections of this report, Chapters II, III, and IV are discussions of each of these three types of interactions in the human ecosystem.

Chapter II is entitled "Food Chains in the Human Ecosystem" to make clear the relationship of the subject matter to the schematic outline of Figure I-1. The word food is taken rather generally to include various other necessities such as fibers (for clothing and paper), drugs, and

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*In most cases the N-1st level is either the 1st or 2nd level (e.g. N = 2 or 3 for most human food chains).

medicines, etc. The chapter could equally accurately be entitled "Requirements and Sources of Necessities." Nutritional requirements are discussed explicitly and at some length* in order to link specific requirements (vitamins, amino-acids, minerals, anti-biotics, etc.) with their main sources of supply. The objective is to evaluate the relative extent to which a thermonuclear attack might affect the availability of various critical elements.

Chapter III, entitled "Diseases and Pests in the Human Ecosystem," covers both direct interactions (diseases of humans) and secondary effects. The organization within the chapter is based on convenient groupings of subject matter which probably require no elaboration here.

Chapter IV is entitled "Abiotic Factors in the Human Ecosystem," and is intended to focus attention on weather and climate, soil (erosion), water supplies etc. The distinction implied in the title is not a precise one, since much of the discussion of these matters devolves upon considerations of ground cover, surface reflectivity (for heat), windbreaks, etc. Thus vegetation (especially forests) is intimately and essentially linked with the whole gamut of "abiotic" factors.+ For this reason one section is devoted to possible effects of thermonuclear attack on forests <u>qua</u> forests.

There are two basic limitations imposed on any study carried out at the present time on the effects of a thermonuclear war on the biological environment. The first limitation is due to the fact that, by and large,

*The fact that ecological studies normally describe food chains purely in terms of energy flow (i.e. Calories) is only due to our lack of detailed knowledge of other nutritional factors in most ecosystems.

+Indeed, if not it would be hard to justify including such a chapter.

studies of ecosystems take place during periods of equilibrium and the present study of the human ecosystem in the North American continent is no exception. Yet the questions to which the study is designed (in some sense) to provide answers have to do with deviations from equilibrium which, to the extent that they are of concern, may be quite violent. The problem is therefore one of prediction and therefore must also involve theory. If the behavior of the human ecosystem for small deviations from equilibrium were thoroughly understood, our task would be to represent its "laws of motion" (as it were) in quantitative or even mathematical form and to use these laws of motion to predict its response to severe disturbances such as a thermonuclear attack might entail. The better the system's ordinary behavior is understood, the more quantitative such predictions of pathological behavior would hope to be.

This leads to the second limitation which this study faces, namely the scarcity of data in certain critical areas. A brief survey of some of these deficiencies was included in the progress report on this contract issued December 15, 1962. For completeness, an updated version is included as Appendix I of this report.

In view of the foregoing a truly systematic study at this time appears impracticable. In our view the most valid approach in these circumstances is to develop "ecological scenarios" which may lead to insights into the complicated mechanisms of the ecosystem. Nature itself provides a number of such scenarios which illustrate various complex interactions. We shall present two examples as Appendices (II and III) to the present report. However, our long term objective is to create hypothetical scenarios which have more direct relevance to the postattack environment. The bulk of our effort

to date, therefore, has been devoted to compiling the basic material by describing and analyzing the elements of the human ecosystem.

§2. Possible Attacks

An exposition of strategic concepts such as counterforce, countervalue, first strike, second strike, etc., would be superfluous here, since all these notions are very thoroughly analyzed in a previous Hudson Institute report for the OCD.[2] It would probably be worthwhile to trace a plausible connection between economics, strategic, military, and political postures and specific attacks with resulting ecological consequences when we come to consider specific scenarios. However, at this stage of the game, it is not possible to formulate simple rules to explain the interrelationships between Realpolitik and biology.

The attack described in the June, 1959 Congressional hearings[3] (so-called Holifield attack) is appropriate primarily for calculations of casualties, property damage, and degradation of military capabilities. The detailed fallout and wind patterns and the complex time-dependent radioactive decay described in the attack were probably of only moderate significance in the economic and military calculations, and only slightly more helpful for obtaining casualty statistics, simply because the demographic, economic and military characteristics of the country are not expressible in analytic form (e.g., mathematical form) which would make it possible to analyze the model and draw conclusions with some confidence. It is reasonable to conclude that most of the conclusions which were drawn from the Holifield attack could have been reached with much less detailed data. When it comes to considering possible biological or ecological consequences of an attack, the difficulty of making analytical connection between the detail of the attack and the consequences becomes overwhelming. It is noteworthy that at the hearings, Dr. John N. Wolfe, Chief of the

Environmental Sciences Branch, Division of Biology and Medicine of the AEC, in his testimony on long-term biological effects, was able to utilize actual details of the Holifield attack with reference to only three remarks:[3]

1. The fact that the Holifield attack took place in the middle of October was noted with regard to the probability of fires spreading over wide regions of the country (e.g. high-probability as against low probability).

2. The fact that Los Angeles was bombed led to the conclusion that the entire watershed would probably be burned.

3. The fact that Pittsburgh was bombed, in conjunction with the fact that Pittsburgh lies over a number of coal seams, suggested the possibility of ignition of underground coal fired (question raised by Representative Durham).

In no other instance was Dr. Wolfe able to relate any of the particulars of the Holifield attack to specific potential biological or ecological consequences.

Until such time as our analytical capabilities improve considerably it would be premature to preface a study oriented toward ecological or biological effects by detailed targeting considerations, wind-patterns, etc. However, to the extent that broad generalizations may still be of some value, we would like to suggest the following three "pure" targeting strategies on the part of a hypothetical enemy.

A. Pure Counterforce

This targeting doctrine would specify military targets only, providing for optimum use of weapons, i.e., airbursts for "soft" targets and groundbursts for "hard" targets such as Minuteman silos. Under this doctrine first priority would be given to SAC bases, second priority to ICBM's, and third priority to supporting installations and dispersal fields. The possible modification of this attack can be envisioned in which only "first-strike capabilities" are attacked, e.g., soft targets only. In this instance it would be a partially disarming attack.

From a point of view of the biological environment, a pure counterforce attack would be of considerable concern since most military targets, especially the higher priority ones, are in relatively unpopulated but generally important agricultural areas. For example, two missile bases (Atlas and Titan) are located in California's rich Imperial Valley and two more are located at eastern Washington, the best fruit-growing, alfalfa and wheat area in the country. The lush irrigated cotton lands around Tucson, Arizona are surrounded by Titan bases. Minuteman complexes are being built in the winter wheat area of Montana, North Dakota, and South Dakota, while other Atlas and Titan sites are scattered through Nebraska, Kansas, and Oklahoma, mostly in the spring wheat area. In fact, missile bases are found near all of the best farming regions west of the Mississippi, although at least half a million square miles of virtually worthless land are availabie in Nevada, Northern Arizona, Southern Utah, and Wyoming. Incidentally, about half of the 224 targets

chosen for the Holifield attack were of military nature (hence the attack had a 50% counterforce component) but only groundbursts were assumed.

B. Pure Counterpopulation (Genghis Khan strike)

Here the targeting doctrine would be to kill the maximum number of people without regard to other considerations and priority would be given to population centers in order of size, e.g., New York, Los Angeles, Long Beach, Chicago, Philadelphia, Detroit, San Francisco, Oakland, Boston, Pittsburgh, St. Louis, Washington, D.C., Cleveland, Baltimore, Newark, Minneapolis, St. Paul, Buffalo, Houston, Milwaukee, Paterson-Clifton-Passaic, Seattle, Dallas, Cincinatti, Kansas City, San Diego, Atlanta.* These areas are also indicated on the map (figure I-2). By and large an attack on the cities would be much less damaging to the agricultural capability of the country than an attack on military installations.

C. Pure Counter-resource

This type of an attack has not been considered at length in the literature on military strategies. Perhaps for this reason we ought to examine the possibilities in somewhat more detail than above.+ It is not possible to give a simple series of priorities for an anti-resource attack. However, it might include the following:

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*The 24 standard metropolitan areas, having a population of an excess of one million in order of size according to the 1960 census.

+The pure anti-resource attack is presumably not a very likely one. However, other kinds of attacks might have anti-resource components. Also, an anti-resource attack could be considered as a step in the escalation ladder between counterforce and antipopulation attacks--the latter being reserved for the "last resort."

1. Dams, power stations, irrigation canals, etc.

2. Drinking water reservoirs

3. Watersheds and forests

4. Oil fields and refineries, pipelines, coal fields, mines

5. Canals, tunnels, mountain passes, strategic railroad junctions, bridges, super highways, microwave relay stations, etc.

6. Orchards, vineyards, livestock and other long-term agricultural resources.

The foregoing represent permanent assets which are difficult, if not impossible to replace, all of which could be destroyed without killing a large percentage of the population. Since the loss of raw materials, electric power, transportation, and water supplies could hobble industry as effectively as physical destruction of plant machinery and workers, a thoroughgoing attack of this sort might leave a high percentage of the population surviving on land incapable of supporting a complex society. A nation in this condition could be conceivably as effectively eliminated as a world power as a nation whose cities had been destroyed.

It should be emphasized that the foregoing three pure attacks are not likely to occur as such since the mixture of motives leading to any real attack is likely also to result in a mixture of strategies. A real attack might consist of 45% counterforce, 30% counter-resource, and 25% counterpopulation, or any other combination. From the point of view of long-term environmental effects, however, it is useful to look at possible attacks in this way.

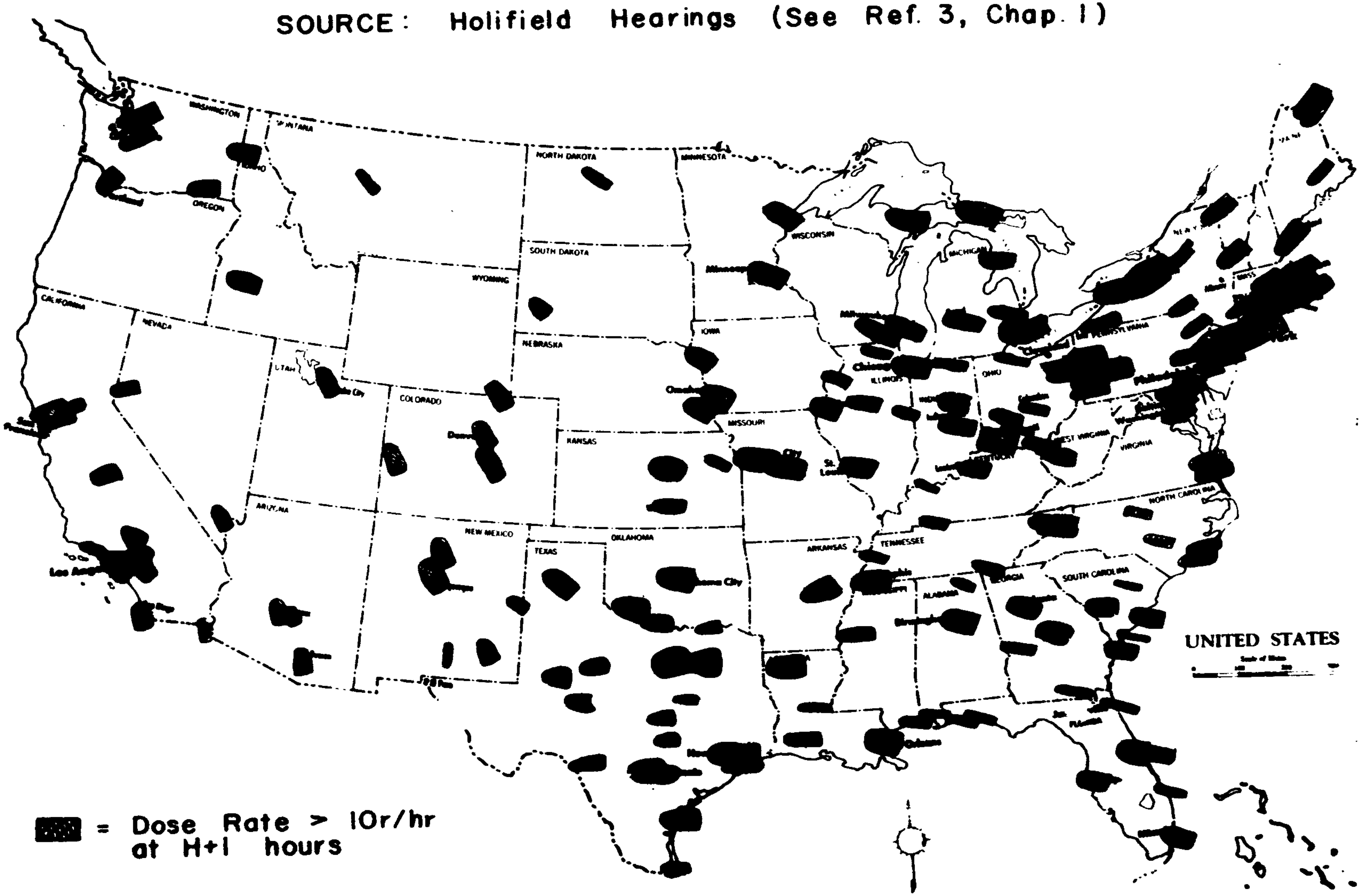
One other variable of importance is the size of the attack, which of course may range from "small" to "large." From the biological point

of view these terms must be defined relative to the amount of disturbance of the biotic environment caused by the war, that is to say a small attack would be an attack resulting in a small degree of ecological imbalance. A useful objective for this study would be to provide some working definition of "small," "medium," and "large" in terms of megatons or other parameters familiar to the military strategists. A preliminary attempt to do this will be found in Chapter V (Conclusions), but the basis for such a calculation cannot be established with high confidence at present.

Two transparent overlay maps will be found in Chapter II in conjunction with the section on crop distribution. Map II-1 contains targets and fallout patterns calculated by the Weather bureau for the "Holifield attack," which was a combined military-industrial attack (1446 megatons) assumed to have taken place in October.[3] Map II-2 contains targets and fallout patterns calculated by Technical Operations Inc.,[4] for a combined military industrial attack (4080 megatons, 2720 fission). Both attacks were assumed to consist of ground bursts. These overlays are designed to show the juxtaposition of targets and fallouts with croplands (Maps II-3 through II-26 in Annex A, Chapter II). For additional quick reference, fallout maps have also been inserted as pages I-16 and I-17, following.

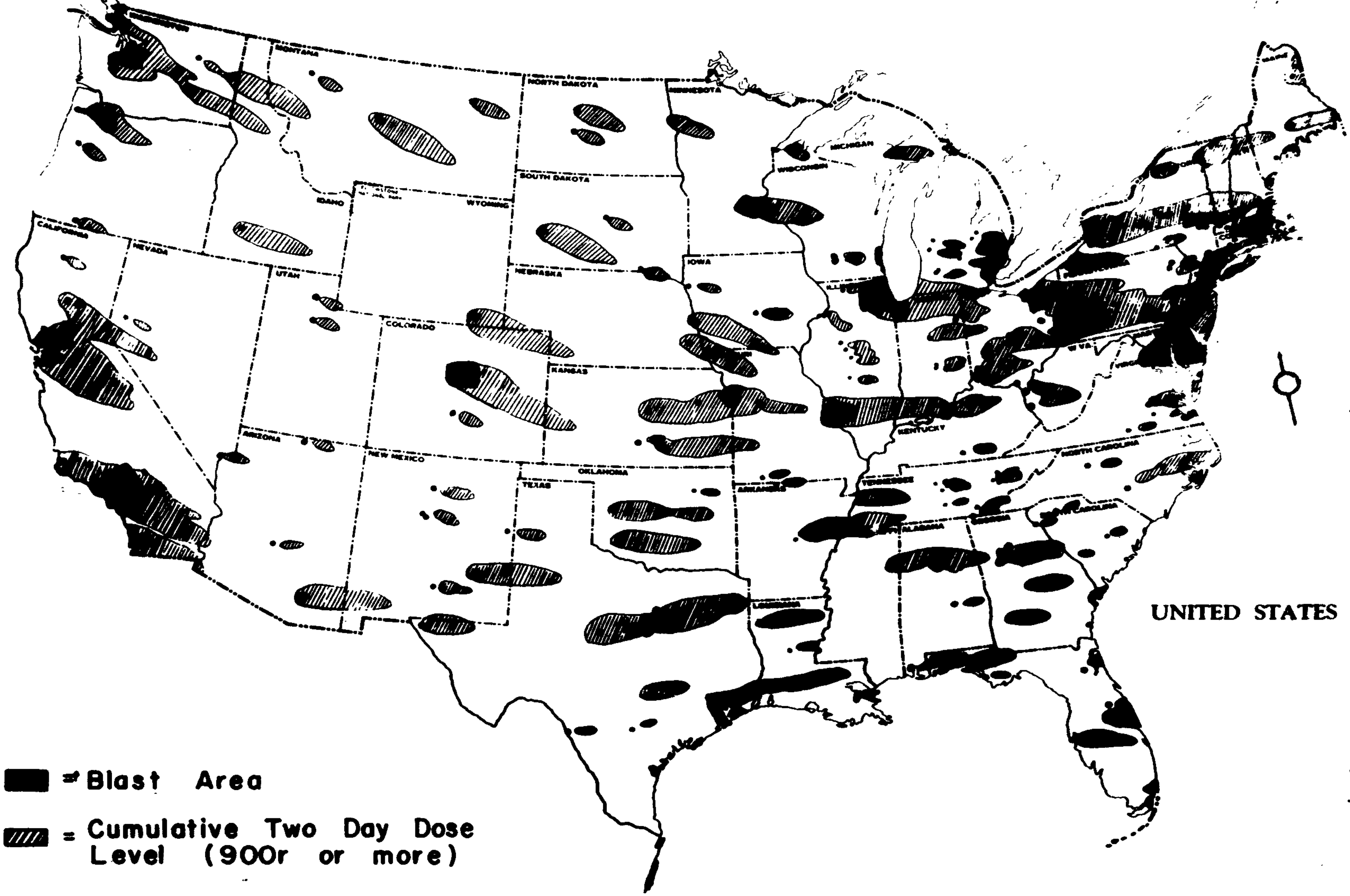
FALLOUT FROM COMBINED MILITARY INDUSTRIAL 1448-MT ATTACK IN OCTOBER

SOURCE: Holifield Hearings (See Ref. 3, Chap. 1)



FALLOUT FROM COMBINED MILITARY INDUSTRIAL 4080-MT ATTACK IN WINTER

SOURCE: Tech. Ops. (See Ref. 4, Chap. I)



■ = Blast Area

▨ = Cumulative Two Day Dose Level (900r or more)

Seasonal Average Winds Assumed

§3 Summary of Information on Radiosensitivities

Radiosensitivities of Cells

Among a large collection of similar cells, the fraction killed by a given amount of radiation will be the same as the probability of a single cell in the collection being killed by the radiation. It has been established that the nucleoprotein (i.e. the chromosomes) is the sensitive portion of the cell. This is not surprising inasmuch as all the vital functions are determined by protein substances within the nucleus and ultimately by the genes. The genes determine not only the reproduction of the cell but all of the complex chemical interactions which take place therein. In a crude sense then, the probability of killing a cell by a radioactive "bullet" is essentially the probability of hitting one of the genes. The foregoing has been expressed as the "target-size theory" of Sparrow, et al.[5]

The target-size theory states that the probability of damage to quiescent cells* is approximately proportional to the cell nuclear volume per chromosome, allowing for small discrepancies due to other factors. Specifically, it appears that the lethal dose in terms of energy absorbed per chromosome is about 3.6 mev or 5.8×10^{-6} ergs. This relationship is still tentative, but has been verified for species with very wide variations in lethal dose, chromosome numbers and cell volume.[6] Nuclear volume has been found to correlate very closely in the species with average DNA content.[7] The latter may be the more fundamental variable.

Measurements of nuclear volume have been made for many plant species. Although no strict correlation has been observed between nuclear volume and taxonomic group, Sparrow and Schairer have noted that many species of

*Cells not actively dividing.

gymnosperms (principally conifers) and monocotyledonous angiosperms have nuclear volumes greater than 400 $\mu 3$ ($\mu = 10^{-6}$ inch), relatively few dicotylae have such large nuclei.[8] Deciduous trees and most economically valuable plants except the grasses and cereal grains (Gramineae) are dicotylae.

There are a number of other factors which must be taken into account in order to refine the predictions made by this theory, of which the most important are as follows:

1. Polyploidy: Sometimes the chromosomes in the nucleus duplicate themselves, but the cell does not split.* If the nucleus contains two copies of each chromosome (the normal situation), it is called a diploid. A cell with a single set is haploid. If more than two copies exist, it is called polyploid. Polyploidy seems to somewhat increase radiation resistance compared to diploidy.+ This is understandable in principle, since damage to one of the chromosomes may not prevent the functions controlled by that chromosome being carried out in the nucleus. The average protective effect for eight pairs of polyploid species differing by a factor of two in chromosome number is 1.67.[9] However, there are contradictory results, particularly for polyploid strains of yeast and the wasp, Habrobracon, at certain stages of development.[10]

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*This process can be stimulated artificially using the biologically active chemical colchicine. It is of use in producing true-breeding, fertile hybrid species, for example.

+Haploidy is a special condition related to sporogenesis in plants or zygogenesis in animals. The process of fertilization (in sexual reproduction) results in haploid cells becoming diploid, with contributions of one set of chromosomes from each parent.

2. Mitotic cycle (growth rate): Mitosis is the ordinary process of cell division involved in growth. The target-size theory is consistent with the hypothesis that the shorter the mitotic cycle--the less time between cell divisions--the smaller the probability of damage occurring during the interphase state (between successive reproductions) as a consequence of a constant level of exposure. This is especially relevant in considering the effects of low-level chronic radiation, where damage to the nucleus can be correlated in some sense to the amount of energy which has been absorbed by the nucleus during the interphase (resting) period. This hypothesis has been tested on Pisum sativum (green pea) by using temperature to control the duration of the mitotic cycle. It was found that the percentage of cells--observed just prior to splitting (anaphase)--having damaged chromosomes increased with cycle duration.[11] Thus, other things being equal, environmental factors which increase the rate of growth or of recovery would also increase the probability of damage. However, as a general rule, rapidly growing cells also have larger nuclei than dormant or slow-growing cells. This may provide an explanation for the otherwise contradictory empirical fact that rapidly growing cells are more radiosensitive than slow growing ones, which is the basis for the use of radiation to destroy rapidly growing cancer cells.[12]

In addition to the factors mentioned above, the "fine structure" of the nuclei may have some importance, e.g. the number and position of centromeres* on the chromosomes; amount and distribution of heterochromatin.+ Similarly, the size and number of nucleoli (small granules inside the nucleus, whose function is imperfectly understood) seem to influence radiosensitivity slightly.[13] Variables not yet identified may also be found to affect the issue. However evidence is piling up that these factors *in toto* are of relatively minor significance compared to nuclear volume--DNA content and chromosome number.

Sensitivities of Plants

It is important to note that the notion of radiosensitivity as applied to complex organisms is much less well-defined than as applied to individual cells. For example, the concept of "lethal dose" is extremely ambiguous in regard to many kinds of adult plants, seeds (and even insects). Some irradiated powder-post beetles (*Lyctus planicollis*) revived after three days of apparent death, and posed difficult problems of judgment for the experimenters.[14] Trees defoliated as a result of long-term chronic doses of radiation, and apparently dead, have been

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*The centromeres are distinguishable during mitosis (as the daughter-chromosomes--chromatids--migrate to opposite poles of the "spindle" during anaphase), as the parts which start first and lead the way.

+Chromatin is the chromosome-substance in the cell nucleus. It has two components: euchromatin ("true" chromatin) which apparently carries the genes, and heterochromatin, whose distinguishing characteristic is that of being easily stained and made visible under a microscope.

known to show signs of life when the radiation source was removed. It is especially difficult to know the precise point at which an underground root system ceases to be capable of vegetation regeneration.* All attempts to tabulate data on plant radiosensitivities must be read and understood in the light of these difficulties (both for the experimenter and the tabulator) Sparrow and Woodwell[15] introduce the following graduated set of responses:

TABLE I-1

Percentage of the daily dose causing 100 per cent mortality (LD_{100}) required to produce various responses in plants chronically exposed to cobalt-60 gamma radiation

Responses	Number of species observed	Daily dose as percentage of lethal dose-100*
Normal appearance	14	less than 11
10 per cent growth reduction	23	26 ± 2·5
Failure to set seed	8	31 ± 5·5
50 per cent growth reduction	12	34 ± 3·5
Pollen sterility (100 per cent)	4	41 ± 4·5
Floral inhibition or abortion	21	44 ± 3·5
Growth inhibition (severe)	41	58 ± 3·0
Lethal dose-50	17	75 ± 2·5
Lethal dose-100	41	100

*Averages (± one standard error of the mean) based on data available for various numbers of species indicated. Most species were herbaceous annuals exposed for 8-12 weeks in the Brookhaven Gamma Field.

Ideally, subsequent compilations should use this or a similar format. Unfortunately most of the available data is not easily translated into a rationalized form. Moreover, not all of the labels (e.g. "inhibition," "severe inhibition," etc.) are precise enough to be understood in the same way by different experimenters.

*Stumps of American chestnut trees "killed" by the chestnut blight 30 years ago sometimes still send up shoots--which are promptly blighted again.

Radiation injury to plants takes various forms, depending on dose:

1. Early leaf-fall, late budding (prolongation of dormancy).
2. Decreased number of buds and leaves.* Growth is slowed or stopped.
3. Chlorosis (yellowing), shedding of needles, etc. Pollen sterile or partly sterile, flowers deformed or non-existent. Pathological disorganization of meristematic tissues (vascular cambium, phellogen, etc.). Visible damage to chromosomes. Enhanced mutation rate.
4. Death.

TABLE I-2

STUDIES OF PARTICULAR TREES PUBLISHED TO DATE

		(References)
Eastern white pine	Pinus strobus	(16, 22)
Pitch pine	P. rigida	(16, 17, 20)
Loblolly pine	P. taeda	(18)
White oak	Quercus alba	(19, 20, 21, 23)
Black oak	Q. velutina	(19, 20)
Scarlet oak	Q. coccinea	(20, 21)
Bear oak	Q. ilicifolia	(20, 21)
Red oak	Q. rubra	(23)

Empirically, the rate at which the radiation is absorbed is extremely significant. For example, Sparrow and Woodwell noted that the lethal dose for Pinus strobus (eastern white pine), when subjected to an average of 20 roentgens per day for 15 months, was over 9,000 roentgens; while an

*Apical meristems (tips of twigs, etc.) are more sensitive than lateral meristems. Heavily irradiated trees are likely to have leaf clusters only near the trunk or the large branches.

acute exposure of only 600 roentgens was fatal for seedlings irradiated over a 16.5 hour period.[24]

Germination of irradiated deciduous tree seeds, and growth of seedlings, has been studied by M. B. Heaslip at Morehead State College, Ky. Some 18 species were covered, including three species of oak, three species of maple, two species of elm, black walnut, shagbark hickory, white ash, black locust, sycamore, sweetgum and several others.[25]

Earlier results for many flowering plants and vegetables have been summarized by Sparrow and Christensen (1953)[26] and Sparrow and Gunckel (1955).[27] The more recent paper gives crude radiosensitivity data for 79 species, including broad bean, kidney bean, tomato, tobacco (5 spp.) lettuce, onion, sweet clover, apple, peach and pumpkin. The others were largely garden flowers, herbs and shrubs.

Work in the U.S.S.R. on germination of irradiated air dried seeds of 80-odd species of plants is summarized by Preobrazhenskaya and Timofeev-Resovskii.[28] This article is of doubtful value for present purposes since germination is an unreliable guide to actual sensitivity. The authors themselves point out that seeds of the grass family (Gramineae) will germinate after exposures to doses from 70 to 140 times greater than the maximum which seeds can withstand and sprout under field conditions.

Sensitivities of Animals

In the case of chronic radiation, life shortening can be predicted (in principle) by computing the cell replacement rates for various physiological functions, and the cell-destruction rate due to the radiation.

Since natural ageing is presumably a function of the degree to which cell replacement fails to keep up with "demand," chronic irradiation can be thought of as an artificially stepped up ageing process. These considerations have been used to predict effects on large mammals.[29] The somatic effects of radiation on humans is thoroughly discussed in the Effects of Nuclear Weapons[30] and the Report of the U.N. Scientific Committee on the Effects of Atomic Radiation[31] for the 17th session of the General Assembly. Since these documents are widely available, we shall not cover the same ground here.

Sensitivities of complex organisms to acute radiation are in some sense determined by the weakest (most radiosensitive) component cells in the organism. However, since death is usually delayed several weeks or months (except for very massive doses) the organism's capability for regenerating the damaged tissue must be taken into account. On the other hand, a dosage which would not necessarily be fatal to an entire population of some particular type of cell might be fatal to the organism as a whole if enough of those cells are destroyed to impair a vital function. The most sensitive part of the human organism, and presumably of most other mammalian species, is the hematopoietic (blood-forming) tissue in the bone marrow, without which the organism soon looses its ability to defend itself against attacks by microbes.* Death resulting from "radiation disease" (of mammals) is usually due to a massive generalized parasitic infection of the whole body at once. However, in considering widely dissimilar organisms, e.g. plants, insects, invertebrates, etc., the

*The epithelial cells lining the intestines are the next most sensitive group, followed by the central nervous system.

mammalian example is not necessarily a good guide, and the immediate cause of radiation death is likely to vary from order to order, if not from species to species. To date many of these detailed mechanisms have not been widely studied.

In passing, we should point out that there are many factors which can apparently alter the degree of susceptibility in mammals. The oxygen level in the blood stream seems to be important. This suggests that a lowered rate of metabolism (e.g. lowered body temperature) or a high level of alcohol in the blood could offer some protection. Considerable research is now in progress to determine whether susceptibility can be substantially reduced by means of various chemicals.[32] Some 1200 compounds had been tested by December 1961 in a major government-sponsored effort directed by Walter Reed Army Institute of Research. As of that time the heterocyclic mercaptoamines appeared most promising, particularly β-mercaptoethylamine. Two- or three-fold protection without undue toxicity has been demonstrated with laboratory animals. Moreover some post-exposure treatment is also reportedly beneficial where pre-exposure protection has been given, expecially at higher levels of irradiation.[33]

Curiously enough there is some surprising evidence of a substantial difference in radiosensitivity (for laboratory rats anesthetized with sodium pentobarbital) between morning and night. Twenty animals (in four different groups) given 900 roentgens at 9P.M. all died within 13 days, whereas twenty animals in four groups given the same dose at 9 A.M. were all still alive and apparently healthy 130 days later.[34]

Table 1-3

RADIATION SENSITIVITY OF HIGHER VERTEBRATES TO ACUTE DOSES [35, 36]

Species	LD_{50}/30 days Air dose(r.)	LD_{50}/30 days Absorbed dose (rads) at midcenter
Dog	281	244
Guinea pig	337	400
Goat	350	237
Mouse	443	638
Swine	510	247
Poultry	800	-
Sheep	524	205
Rat	640	796
Burro	651	256
Monkey	760	546
Rabbit	805	751
Cattle	500	-
Man	450?	-

In the case of insects there is often a significant variation from one stage of the insect's life cycle to the next. During the stages when cells are rapidly differentiating, some insects seem to be sensitive to instantaneous doses of a few hundred roentgens or less. However, resistance increases very rapidly with maturity. Adult insects seem to be highly insensitive, on the whole, mainly because there is practically no cell-replacement. Instantaneous doses are again much more effective than cumulative doses. Adult insects may, however, be sterilized by radiation substantially below the lethal dose. The well-known use of sterilized males to eliminate the screw-worm fly, Callitroga hominivorax, from Curacao[37] is a practical application of this fact. (Details are given in Table I-4.)

Shielding and β-Dose

No discussion of radiosensitivities can be complete without some mention of β-sensitivity and the associated question of shielding. As will be pointed out at several points in this report, the β-component of typical fallout debris could contribute roughly a dose equivalent to approximately 40 times the γ-dose on any square centimeter of exposed surface. However, even a few centimeters of air or a few millimeters of any solid (e.g. organic) material is sufficient to absorb or shield out most of the β-particles. For small organisms such as insects, or exposed external tissues, the β-component of fallout would probably be much more important than the γ-component, where direct contact with the fallout debris occurs.

In the case of plants, the crucial questions are how deeply buried the sensitive meristematic tissues are, and to a somewhat lesser extent, the protection afforded by the over-all configuration and life history of the plant. For animals, similar questions must be considered, plus the degree of natural shelter which the animal's habitual environment is likely to afford. Thus plants may or may not reproduce vegetatively from rootstock, the above-ground portion may or may not die back annually, etc.

Table I-4 (1)

RADIATION SENSITIVITY OF INSECTS[38, 39]

COMMON NAME	SCIENTIFIC NAME	TYPE OF RADIATION	DOSAGE, r	KILL %	TIME ELAPSED BEFORE DEATH (DAYS)
Black Carpet Beetle	*Attagenus piceus*	γ			
larvae			16,100	100	80
			32,200	"	70
			64,400	"	60
			128,800	"	26
			193,000	"	16
			257,600	"	3
adult			64,400	100	12
			193,000	"	2
			322,000	"	1
Rice Weevil	*Sitophilus spp.*	γ			
adults			16,100	100	12
			32,200	"	12
			64,400	"	7
			128,800	"	5
			193,000	"	2
			257,600	"	2
Lesser Grain Borer	*Rhyzopertha Spp.*	γ			
adults			16,100	100	48
			32,200	"	40
			64,400	"	23
			128,800	"	9
			193,000	"	6
			257,600	"	4
			322,000	"	1
Wasp, male	*Habrobracon spp.*	x	2,500	50*	
Wasp, male		x	7,500	almost total*	
Wasp, female		x	5,000	total*	

Table I-4 (2)

RADIATION SENSITIVITY OF INSECTS[38, 39]

COMMON NAME	SCIENTIFIC NAME	TYPE OF RADIATION	DOSAGE, r	KILL %	TIME ELAPSED BEFORE DEATH (DAYS)
Screw worm fly	*Callitroga Hominivorax*				
pupa male		x	2,500	total*	
pupa female		x	5,000	total*	
6 day pupa		x	5,000	total*	
Flour Beetle	*Tribolium confusum*	γ			
adults			16,100	100	13
			32,200	"	13
			64,400	"	14
			128,800	"	9
			193,000	"	6
			257,600	"	3
			322,000	"	1
Cigarette Beetle	*Lasioderma serricorne*	γ			
adults			16,100	100	12
			32,200	"	12
			64,400	"	12
			128,800	"	16
			193,000	"	12
			257,600	"	3
			322,000	"	2
Powder Post Beetle	*Lyctus planicollis*	γ	64,000	90	7
			32,000*	100*	
Fruit Fly	*Drosophila melanogaster*				
3 hr. egg		x	170-200	50	
3 hr. egg		Fast neutrons	30	50	
4 hr. egg		x	500	50	
7.5 hr. egg		x	810	50	
Pupal		x	2,800	50*	
Adult		γ	64,400	100	21
Adult		γ	193,000	100	2
Fasted Adult		β	60,000	100	1
Fed Adult		β	60,000	60	14
			84,000	90	

*Refers to sterilization dose

Table I-4 (3)

RADIATION SENSITIVITY OF INSECTS[38, 39]

COMMON NAME	SCIENTIFIC NAME	TYPE OF RADIATION	DOSAGE, r	KILL %	TIME ELAPSED BEFORE DEATH (DAYS)
Larder Beetle	*Dermestes* spp.	γ			
larvae			16,100		died during pupal stage
			32,200		" "
			64,400	100	6
			128,800	"	4
			193,000	"	4
			257,600	"	3
			322,000	"	3
adult			16,100		died during pupal stage
			32,200		" "
			64,400	100	13
			193,000	"	3
			322,000	"	1

Similarly, animals may have habits which would tend to expose them to β-radiation, or vice versa. These points are discussed in Chapter III.

Mutations

In using the term "sensitivity" throughout the foregoing discussion we have been referring to probability of injury or death. Radiation can have other biologically significant effects, especially in regard to inducing mutations, as has been demonstrated by numerous experiments on the fruit fly, Drosophila, and other organisms.[40] In recent work Sparrow and Shairer have shown that frequency of mutation is correlated closely with nuclear volume per chromosome.[41] The importance of enhanced mutation rates in connection with possible outbreaks of fungal diseases and other pathogens is discussed in Chapter III.

Sensitivities of Ecosystems

Radiation sensitivity of complete ecosystems is an even less well-defined notion. Studies of the effect of radioactive fallout on ecosystems as a whole have been mostly *ex post facto*, e.g. observations made after a nuclear test has taken place. The ambitious cooperative programs of the University of Washington (with regard to nuclear testing in the Pacific) and New Mexico Highlands University and Brigham Young University (in conjunction with the testing in Nevada) are of this type. Similarly the ORNL and Hanford programs are carried out in conjunction with disposal of radioactive wastes. Such studies are well-suited for investigating food chains and cycling of radio-nuclides, but inherently inappropriate for obtaining quantitative data on ecosystem response to radiation.

Major programs suited for determining ecosystem sensitivity and response are carried on at Brookhaven and Emory University, Georgia,

though small-scale studies exist elsewhere. Results are very sparse and tentative, at present, but some are interesting and worth quoting. Such information as is now available is not suitable for compact tabular presentation but reference will be made to the literature at various points in the later chapters.

TABLE I-5

STUDIES OF IRRADIATED ECOSYSTEMS

	(References)
Nevada Test site (desert community)	(42, 43)
Abandoned cornfield in Georgia	(44)
Granite outcrop in Georgia	(45)
Oak-pine forest in Georgia	(46)
Oak-pine forest in Long Island	(47, 48, 49)
Abandoned potato field ("old field") in Long Island	(49)
Coral attoll (Gegen) in Marshalls	(50)

§ 4. Summary of Information of Radio-nuclide Cycling

The cycling processes which lead to the appearance of radioactive nuclides such as Sr_{90} in the human food supply have been studied extensively. The results of these studies have been summarized quite adequately in the U.N. Report previously cited[31] as well as other documents.[51] There is no need to go over this material here.

The above studies do not throw much light on the effects of radio-nuclide cycling elsewhere in the environment. The reason is that the human food chain has been artificially simplified. In the United States about a quarter* of the food for human consumption comes directly from cultivated plants and well over 90% of the remainder derives from domestic animals fed largely (66%) on cultivated plant sources, the remainder being natural pasture.[52] Almost the only foods arising from more complex chains are sea-foods and fresh water fish.[53] A negligible proportion of human food arises from wild birds and game.

The U.N. study provides a fairly adequate picture of radio-nuclide cycling in the simple one- and two-step chains which constitute the great bulk of human food sources. Studies of the more complex chains, however, are both more difficult and have received much less attention. In the environment as a whole, however, the more complex chains are much more important than the above (dietary) considerations would seem to indicate. For example, in the following we shall emphasize the role of insects in the environment. To date, radio-nuclide cycling in insect food chains

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*By calories.

hardly seems to have been studied at all.* Yet such studies may be of vital importance.

A purely hypothetical illustration may be worth making at this point. In a postattack situation it is all too probable that two of the three major controls on insect population explosions may be at least temporarily missing; namely, insectivorous vertebrates (birds, bats, rodents, lizards, etc.), and chemical insecticides.+ In this situation the importance of insect predators would be enhanced. Now consider the pea aphid, a pest which consistently destroys a substantial percentage of garden crops and alfalfa all over the United States, despite the best continuing efforts of the birds, the USDA and the farmers. An insect predator which devours

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*A few related studies exist:

i.) Genetic studies based on feeding the isotope P_{32} to induce mutation (on the fruit fly Drosophila melanogaster and Drosophila virilis).[54]

ii.) Studies of the distribution of P_{32} in wax moth, mealworm, cockroach and firebrat.[55]

iii.) Genetic studies using P_{32} on the parasitic wasp Habrobracon. (It was found that 60% of the P_{32} fed to females was incorporated into eggs, leading to some degree of infertility.[56] Studies have also been made of Habrobracon reared on host larvae injected with Ca_{45} and Sr_{89} isotopes. Both were incorporated in sperm[57] but are not found in adult tissues.

iv.) Ecological studies on the consequences of waste disposal near Oak Ridge[58] indicate that herbivorous insects accumulate Cs_{137} (in muscular tissue, mainly) to the extent of the contamination in their food, but that Sr_{90} is somewhat discriminated against. Ecological studies of aquatic systems in the vicinity of AEC installations also have followed isotopes (mainly P_{32}) from algae into the fish and waterfowl food chains.[59]

v.) Ecological studies using P_{32} as a tracer to untangle complex food chains.[60]

+This is based on the assumption that, in general, vertebrates are far more sensitive to radiation than insects, and that in the postattack chaos, either the manufacturing capacity for chemical insecticides of the distribution capability may be seriously damaged.

enormous quantities of aphids is the lady-beetle. Each lady-beetle will consume several hundred aphids in a normal life span, each of which, if not eaten, is capable of parthenogenetically producing several more aphids or laying hundreds of eggs within a few weeks. Now suppose, for purposes of argument, that aphids have an affinity for radioisotope "X" which is concentrated by the aphids' metabolism in sub-lethal quantities. In the normal course of events a lady-beetle feeding on aphids will therefore ingest several hundred times as much radioisotope X as each of its prey. Unless the isotope is passed very quickly out of the lady-beetle's system (e.g. unless the isotope is discriminated against), or decays very rapidly the lady-beetle may ingest a lethal quantity or, equally bad, it may ingest enough to sterilize its eggs. In either event, even if the intrinsic resistance to radiation on the part of lady-beetle is higher than for aphids (unlikely), the lady-beetle population runs a higher risk of damage from radiation.

Since there are some two hundred radio-nuclides present in typical fallout, some of which decay fairly slowly,* the possibilities for this sort of biological concentration are very real. Moreover, since insects have fairly similar metabolisms, there is some probability that if aphids concentrate isotope X, then lady-beetles may also concentrate it. Hence, for slowly decaying isotopes, the inherent likelihood of damage seems to increase somewhat with trophic level. That is to say, the higher the position in the food chain the higher the probability of ingesting dangerous amounts of radioisotopes due to concentration by the previous steps in the chain. Admittedly most of the radio-nuclides decay very fast even

*In this context "slowly" would mean having a half-life comparable to or longer than the insects' life-span.

compared to insect life cycles. Thus in many instances the effect of concentration is balanced or outweighed by the rapid decay. In such cases the effect works in reverse: the prey get larger doses than the predators. However, the important point is that biological concentration is more likely to be important for insect predators with short life cycles than for larger animals such as birds or fish with longer life cycles and much slower feeding rates. Table 1-6 illustrates one case (P_{32} in an aquatic food chain) where radioactive decay does balance and finally outweigh biological concentration.

Hypothetical examples of this sort just given could be constructed almost at random. Yet at present there is little solid data applicable to this subject. Information on the cycling of radioisotopes, particularly among insect and invertebrate populations, is probably potentially as important as data on individual radiosensitivities from the civil defense point of view. Theoretical work done by Sparrow and others (see § 3 in this chapter) makes it possible to predict with reasonable success (e.g. within 50% or so) the radiosensitivities of different orders and species of plants and, to a lesser extent, insects in the early stages of their life cycle. Much less theoretical work exists to provide explanations of the movements of radioisotopes within complex food chains, although mention should be made of the work of Bowen and others on mineral metabolism in insects.[61] The handling of the basic data may require some special techniques, perhaps analogous to the "input-output" analysis used in economics. An interesting approach using analog computers has been developed at ORNL by J.S. Olson.[62]

TABLE I-6 [63,64]

Cycling of Radio-phosphorus in Aquatic Food Chain
(Columbia River, near Hanford)

	Microcuries P_{32} per gram of P_{31}
water	25
plankton	25
sessile algae	25
sponge	20
caddis-fly larvae	17
snails	8
fish	5
crayfish	2

P_{32} half-life = 14 days
Materials were collected at different times, hence comparisons are of dubious value. See below:

	Time of peak radioactivity from one injection of P_{32} *	
water	0	hours
plankton	10	"
sidewall algae	5-10	days
animals feeding on side wall algae	11-18	"
mud algae	15-25	"
sediment	still increasing after 50 days	

*For water having low initial P_{31} content, only 2-5% of P_{32} remains after 30 days. For initial high P_{31} concentration, 80-90% of P_{32} remains (allowing for decay).

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CHAPTER II

FOOD CHAINS IN THE HUMAN ECOSYSTEM

This chapter discusses the requirements and sources of various elements, needed by humans, having a biological origin. The word "food" is too narrow, strictly speaking, though most biological necessities are, in fact, foods, and foods are the most necessary. (In deciding what is necessary and what is not we rather arbitrarily include drugs, clothing, and shelter only. Of these, clothing and shelter are deemed unlikely to be problems.)

Section §1, then, is devoted to the possible effects of nuclear attack on human nutrition.

Section §2 is primarily a discussion of the geographical distribution of various agricultural crops. Annex A contains maps indicating the distribution of specific crops with transparent overlays showing targets and fallout patterns for two possible attacks on the United States.

Section §3 mentions certain quasi-artificial food sources (e.g. super-simplified ecosystems) which have received attention in connection with problems such as space travel. Possible implications for a post-attack environment are discussed briefly.

§1. Nutritional Factors in a Postattack Environment

One of the penalties of being one of the more advanced products of evolution is that man--as well as other animals--has lost the ability to synthesize all of the chemicals which make up his protoplasm, and supply energy for metabolism, from their most elemental forms, i.e., from simple substances and sunlight. In the past 50 years, considerable research has been devoted to isolating both the basic raw materials necessary in the human metabolism and those more complex substances which must be supplied essentially in a prefabricated form. These are classed as energy sources, proteins (amino acids), vitamins, essential fatty acids (lipids), and minerals. In a postattack environment the availability of each element of nutrition would probably be affected in a different way.

A. Calories*

It cannot be stated categorically that food energy would be plentiful in a postattack environment, but caloric shortages, if they did occur, would probably be accompanied by much more severe shortages of other nutritional elements. On the average, carbohydrates provide 4.1 Calories/gram; fats, 9.5; and proteins, 5.7. Daily requirements range from 2000 to 5000, depending on age, weight and activity. Energy content or Caloric value of standard foods is well known, frequently tabulated and readily available. For this reason it tends to be somewhat overemphasized in many popular discussions of nutrition. Indeed, there may be some justification for this when the problem being considered is to supply a diet meeting

*To avoid confusion we follow the standard convention and define 1 Calorie = 1000 calories, when the (uncapitalized) calorie is the amount of heat required to raise the temperature of a 1 gram of water 1 degree C.

certain elementary requirements under special conditions for some limited period of time. For example, there has been some discussion of the dietary requirements of a man on an interplanetary journey through space where the primary concern is to supply at least the minimum energy needs in compact and relatively efficient form (see section §3 of this chapter).

B. Proteins (Amino Acids)

Proteins are found in every living organism, in every part of the body and are in fact in some sense the sine qua non of life. All proteins which are ingested must be broken up by the digestive system into component amino acids from which subsequent body proteins are constructed. All of the common proteins found in plant and animal foodstuffs are constructed from approximately 25 basic amino acids. Many of the 25 amino acids can be synthesized in the human body (listed in Table II-1); although some of these need additional supplements from the diet. The eight "essential amino acids" which must be supplied from the diet are given in Table II-2. Ratios of these essential amino acids vary from food to food, but in vegetable sources three amino acids, tryptophan, lysine and methionine are consistently rare. In the most plausible postattack source of supplemental dietary protein--brewers yeast--lysine and tryptophan are supplied adequately but methionine (and cystine) are not. Methionine is the common denominator for both of these cases and might be a critical factor in posattack diets. Tables of amino acid contents of common foods are supplied in all texts on nutrition, and will not be reproduced here.

TABLE II-1

Amino Acids Made by the Body

Glycine	Tyrosine
Glutamic acid	Cystine
Alanine	Cysteine*
Proline	Hydroxyglutamic acid
Hydroxyproline	Norleucine
Aspartic acid	Di-iodo-tyrosine
Serine	Histidine+
	Arginine+

TABLE II-2

Essential Amino Acids[1]
Daily Requirements

Amino Acid	Value proposed tentatively as minimum grams per day	Value which is definitely a safe intake grams per day
Tryptophan	0.25	0.50
Phenylalanine	1.10⊥	2.20
Lysine	0.80	1.60
Threonine	0.50	1.00
Valine	0.80	1.60
Methionine	1.10‡	2.20
Leucine	1.10	2.20
Isoleucine	0.70	1.40

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* Cystine and cysteine are closely related chemically. Cysteine is very unstable and is easily oxidized to cystine. Both, along with methionine, are sulfur-containing amino acids.

\+ Histidine and arginine are essential for children.[2]

⊥ On diet devoid of tyrosine. Presence of suitable amounts of tyrosine may reduce the phenylalanine requirement by 70-75%.

‡ On diet devoid of cystine. Presence of suitable amounts of cystine found to reduce by 80-89% the amount of methionine required.

Note: The so called essential amino acids were distinguished experimentally from the inessential ones by "nitrogen balance" only. An inessential amino acid is defined as one which, when absent from the subject's diet, induces no change in the state of the nitrogen balance. The mere fact that there is no change in the nitrogen balance after an experimentally induced amino acid deficiency does not mean that the deficient amino acid was not an "essential" one in some sense.[3]

C. Vitamins

Vitamins are, loosely speaking, chemical substances required by the body in small quantities for normal functioning, which are not otherwise classified (e.g. as amino acids or fatty acids). New candidates for vitamins are at least tentatively proposed in the technical literature every few months. Until such time as the human body chemistry is much more thoroughly understood than it is at present, it will not be safe to replace natural foods for any substantial period of time (say, six months or longer) by artificial substitutes* for the simple reason that the synthetic versions contain only those elements which are known and, of course, leave out vitamins and chemical substances of importance whose role in the metabolic process are not as yet understood. For a list of the recommended daily vitamin requirements see Table II-3.

(1) B-Complex vitamins

To a certain extent the B-complex vitamins can be synthesized by intestinal bacteria. However, these symbiotic bacteria require para-aminobenzoic acid (PABA) and possibly lactose and poly-unsaturated fat for their own needs. They are susceptible to sulfa drugs as well as the antibiotics, streptomycin, aureomycin and penicillin. Secondary results of a thermonuclear war such as widespread radiation, lowered disease resistance, and a breakdown of sanitation and public health controls, might lead to epidemics of enteric diseases ranging from vague diarrheas

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*Although this has been done successfully for rats in a laboratory environment. However (i) much more is known about rat nutrition than human nutrition, since rats are much easier to experiment on; (ii) rat nutrition and human nutrition are emphatically not the same (for example, rats do not require vitamin C); and (iii) the artificial diets are only known to be adequate for an animal in a cage leading an "easy" life. (This is an important remark.)

TABLE II-3

Recommended Average Daily Adult Vitamin Requirement

A	5000 USP Units or 1.5 mg.
D	400 USP units in pregnancy, childhood and adolescence.
E	14-19 mg.; deficiency is not likely in a "normal" diet due to widespread distribution of vitamin E in foods.
C	75 mg.--optimal adult requirement.
B Complex:	
B_1 (thiamin)	0.5 mg. per 1000 Calories.
B_2 (riboflavin)	1.6 mg.
Niacin	15 mg. or 20-25 mg. if taking sulfa drugs.
B_6	1.2 mg.*
Pantothenic acid	Unknown, but probably less than 5 mg. (A deficiency disease has not been identified for man.)
Folic Acid	Unknown, but probably less than 0.2 mg.
B_{12}	Unknown, but probably less than 1 microgram+
Choline	Less than 500 mg. (Diet usually furnishes 250-600 mg.)
Inositol	Less than 1 gm. "safe" level of intake.
Biotin	Unknown.
Para-aminobenzoic acid (PABA)	Unknown.
K	Adult requirement not established. 1 mg. daily during last month of pregnancy.
P	Not established.

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* In animals the B_6 requirement is increased by methionine and by sucrose in the diet; it is apparently reduced by choline, essential fatty acids, biotin and pantothenic acid.

+ This amount will induce remission of experimentally induced pernicious anemia. B_{12} deficiency has been observed in long-standing vegetarian diets. This has some relevance to possible post-attack situations. A "normal" diet is estimated to contain 8-15 micrograms.

and "intestinal flu" to bacillic dysentery and typhoid fever. These diseases, or their treatments,* often interrupt the useful activities of intestinal bacteria leading eventually to B-vitamin deficiencies some of which would go unrecognized. The consequences for populations weakened by radiation and under severe environmental stress may be very serious.

In addition to the B-complex vitamins listed in Table II-3, there are several other possibilities being reported on in the literature, for example, lipoic or thioctic acid, vitamins B_{13}, B_{14}, and pangamic acid (B_{15}). There are also possibly other B-vitamins called variously antifatigue, antitoxic or antistress vitamins which appear to be unnecessary under normal conditions or needed only in very small amounts such as might be produced by bacteria in the intestines. However, under conditions of stress such as produced by drugs, or chemicals, or infections, pain, noise, fatigue, or other factors (including radiation sickness) these vitamins, which seem to be present mainly in animal liver, might be extremely important. Davis[4] cities laboratory animals made to swim in ice water. Fed normal diets, they lived only three to ten minutes; but when given extra liver they survived immersions as long as two hours under the same conditions!

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* Sulfonamides are chemically similar to PABA and are taken up by bacteria in preference to it. Hence the value of sulfa drugs against bacillary dysentery. (See also Chapter III.)

(2) Vitamin A

Vitamin A is found in all green vegetables as well as many root crops which may be safer to eat, and can be stored better than leafy vegetables. Fish oils and seed oils are the major commercial source, and, given a reasonable degree of social organization, fishing as an industry should continue. Many commercial fish canneries are in relatively unpopulated areas, e.g. Alaska, Maine, Samoa, Nova Scotia, etc. Critical situations are most likely to arise, if at all, as a result of transportation or distribution dreakdowns rather than basic shortages. The fact that Vitamin A is easily stored in the body (mainly in fatty tissues) tends to make short-term problems unlikely.

(3) Vitamin D

In a postattack situation where large numbers of people may be confined indoors for long periods in order to minimize contact with radioactive contamination, a vitamin D shortage is a real possibility. Commercial vitamin D cannot be synthesized artificially and is obtained from yeast or from fish liver oils,* although any animal liver is a good source and any animal fat is likely to contain at least some. Vitamin A and vitamin D are almost always sold together commercially, so the above comments in regard to vitamin A apply largely to vitamin D also.

Exposure to ultra-violet light enables the normal adult body to produce its own vitamin D supplies. Hence sunlight (or u-v) lamps are the only real requirement for all except young children.

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* By irradiating the component sterols with ultra-violet light.

(4) Vitamin E

Among other functions (mostly not well understood) vitamin E is an antioxidant which, in the body, protects vitamin A and other unsaturated fatty acids against oxidative destruction. The liver of an animal deprived of vitamin E tends to be rapidly depleted of its Vitamin A content. (However, a healthy individual with a good supply of stored vitamin A can survive for up to two years without any additional vitamin A in the diet.) The antioxidant property of vitamin E may protect red blood cells from hydrogen peroxide, which is produced in the blood from water molecules by ionizing radiation. However, despite this useful property vitamin E appears to have no effect in mitigating the effects of radiation, at least when the vitamin is supplied in excess doses. On the other hand, it seems possible that a deficiency of vitamin E would degrade the body's resistance to radiation.

(5) Vitamin C

Apart from its well-known antiscorbutic activity and other functions, vitamin C seems to be particularly important in the production of phagocytes and antibodies. Since the principal result of radiation sickness is degradation of the body's ability to fight infections by producing antibodies, vitamin C would be of critical importance in a postattack environment. Vitamin C is also a rather generalized anti-stress factor, enabling the body to adjust to temperature extremes and other environmental influences. Massive doses (up to 1000 mg.) are sometimes recommended, though the scientific basis for this is thin, since the kidneys rapidly remove excess vitamin C from the blood stream.

(6) Vitamin K

This vitamin is essential in the production of prothrombin, which, in turn, is required for the formation of fibrin, one of the constituents of blood clots. In humans vitamin K is normally supplied by intestinal bacteria, with the exception of newborn infants, whose intestines are sterile. The principal cause of deficiency in adults is likely to be prolonged treatment by antibiotics or possibly some other severe disturbance in the intestinal tract.

D. Essential Fatty Acids

Only three of the many fatty acids are termed "essential" because the body requires but does not synthesize them. These are linoleic acid, linolenic acid and, to a certain extent, arachidonic acid. Linoleic acid is the most important for dietary purposes, although to some extent it can be substituted for by linolenic acid. Linoleic acid is found in nuts, seeds, kernels of cereal grains and animal fats, especially liver and other glands. Soybean oil, cottonseed oil, and corn oil contain up to 50% linoleic acid (the "polyunsaturates" of modern dietary literature). Since the most plausible postattack diet would depend heavily on whole cereal grains (rather than refined flour, etc.) the ratio of unsaturated to saturated fatty acids in the diet would probably be higher than at present. In this respect, at least, the population would probably be healthier than it is now.

E. Trace Minerals

As a general rule, minerals are taken up by plants in sufficient quantities to supply human needs, providing the plants are grown in soil containing the requisite minerals in the first place. Calcium and

phosphorus, generally used together by the body, are primarily derived from milk and dairy products--about 73% presently in the United States. Calcium is important because the most dangerous long-lived component of fallout, Sr_{90}, is taken up by the body as a calcium surrogate. If calcium is in short supply, more radio-strontium will be absorbed by the tissues and incorporated into bones and teeth. Hence an adequate supply is important while the normal sources are unavailable (e.g. contaminated forage). If mineral supplements are supplied they should contain calcium and phosphorus (e.g. manufactured from bone meal) as well as iron and iodine. Other possibilities are to use iodized salt and reprocess limestone into a soluble calcium powder. See Table II-4 below for daily mineral requirements.

TABLE II-4[5]

Element	Approximate % of Adult Human Body	Minimum Daily Requirement	Recommended Daily Intake
Calcium*	2.2	.55 gm/day	1.0 gm/day
Phosphorus+	1.2	.3 "	.6 "
Potassium	0.35	1.5 "	
Sulfur	0.25	.8 "	
Chlorine	0.15	.8 "	
Sodium	0.15	.2 "	
Magnesium	0.05	.15 "	
Iron	0.004		12** mg/day
Manganese	0.0003		
Copper	0.00015		1** mg/day
Iodine	0.00004	.014 mg/day	excess stored
Cobalt	⊥		
Zinc	⊥		
Molybdenum	⊥		
Others of more doubtful status			

* Estimates vary widely.

\+ Percentage varies with that of calcium. Ca/P ratio is normally just under 2.

⊥ Quantitative data seem insufficient for numerical expression here.

** Higher during pregnancy and lactation.

F. Remarks

In speaking of dietary requirements, it should be understood that we are not necessarily referring to the absolute minimum requirements for physical survival. There is practically no evidence which would allow one to define such a minimum. It is true that human beings may survive (e.g. in a postattack environment) on diets which are extremely deficient. Many of the symptoms of vitamin deficiency such as pellagra, rickets, scurvy, beri-beri, and pernicious anemia are not in themselves fatal. In general the results of shortages are, at first, a general weakening of the organism (especially its ability to withstand environmental stress and disease). As the deficiency continues, a chain of events is initiated which ends in death if the supply is not renewed. To reverse the process is not a simple matter. After a long-term shortage it is not possible to build up the supply in the bloodstream and the cells to its optimum point in a short time. Generally it takes months or years for the proper equilibrium to be restored.

The most likely deficiencies in a postattack environment would be the essential amino acids and the water soluble vitamins because these two food elements must be restored almost daily.* The water soluble vitamins (B-complex and C) are not only not retained in the human body to any extent, but they are easily destroyed in stored foods by heat, light or various enzymes.

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*It should be clear that supplies of these vitamins are present at all times in the body, and are not all used up in a single day. The requirements spoken of are essentially the quantities which would be required by the metabolism in a day without depleting the active supply of "rotating inventory." In the case of vitamin C, for example, it has been found experimentally that three or four months would have to pass before the body's supply of vitamin C was reduced to zero, assuming no special need for the vitamin arose during the interim.

§2. Sources of Important Substances of Biological Origin*

The word "food," as it is used by ecologists, might logically be stretched to include other necessities or inputs of the human ecosystem. In the general sense of necessities for an organized society, one might reasonably include shelter, clothing, medicine, and the biological raw materials of industry. The extent to which any of these become critical depends in detail upon the nature and severity of the postattack situation being discussed. For example, much depends on whether cities and industry survive or not.

A thorough analysis would involve factors well outside the scope of biology. Exercising some restraint, therefore, we might include in the "food chain" as necessities: fibers (cotton, flax, wool, etc.), forest products (wood, paper pulp, turpentine, alcohol, etc.), and medicines from biological sources (anti-biotics, steroids such as cortisone and ACTH, insulin, etc.). Since forests perform the dual function of supplying usable crops, and protecting watersheds and controlling erosion and runoff, we discuss forests separately in Chapter IV rather than in this chapter.

Fibers are unlikely to be in acute short supply in the short run, due to tremendous existing supplies of clothing, paper, etc. Reprocessing of existing supplies, if necessary, is not difficult. Moreoever, there is a large margin between minimum fiber requirements and our current consumption which incorporates vast amounts of fiber used luxuriously or wastefully.

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* Two general references for the topics covered in this section are Postattack Farm Problems prepared for the OCD by Stanford Research Institute (1962)[6] and the U.S.D.A. Yearbook. Land. (1958).[7]

Another class of products consists of biological substances not native to the United States (imports). In this category are rubber, cork, hemp, copra, rotenone and pyrethrins, opium derivatives, and many others. A nuclear catastrophe of sufficient magnitude could conceivably effect these sources of supply, but this question introduces many complex extraneous issues.

The salient fact, revealed by Figure II-1, is that a very small percentage of arable land in the United States is presently devoted to food for domestic consumption (excluding feed for animals). Yet we shall see that from this small slice of the land "pie" (about 8% of the land suitable for cultivation) from 1/2 to 2/3 of the basic (Calorie) requirements of a minimal diet can be obtained. Consider the principal food crop, wheat. So large is the production compared with domestic demand, that approximately half of the output is available for export. Thus, in 1959, 1,126,000,000 bushels of wheat were harvested, and 510,000,000 bushels were exported--46% of the total.[8] Disposition of the principal crops in 1959 is given in Table II-4. Varying percentages of each year's production are purchased by the Commocity Credit Corporation and put into storage. As of March 31, 1963 1,010,410,225 bushels of wheat were held in inventory by the government.[9] It is estimated that this would be enough to feed the entire population of the United States for at least a year. Table II-5 gives the quantities of meat, poultry, dairy products, and grain products consumer per capita by Americans each year. A second column gives the number of pounds of feed required to produce the amount of each animal product given in the first column. A pound of feed in Table II-5 is considered to be equivalent to one pound of corn in feeding value. Roughly two-thirds of all the feed given to animals is grain or related products derived from crop lands. The remaining one-third comes from pasture and grazing land which could not be conveniently used to grow crops for direct human consumption.

FIG. 11-1

LAND USE IN THE U.S.

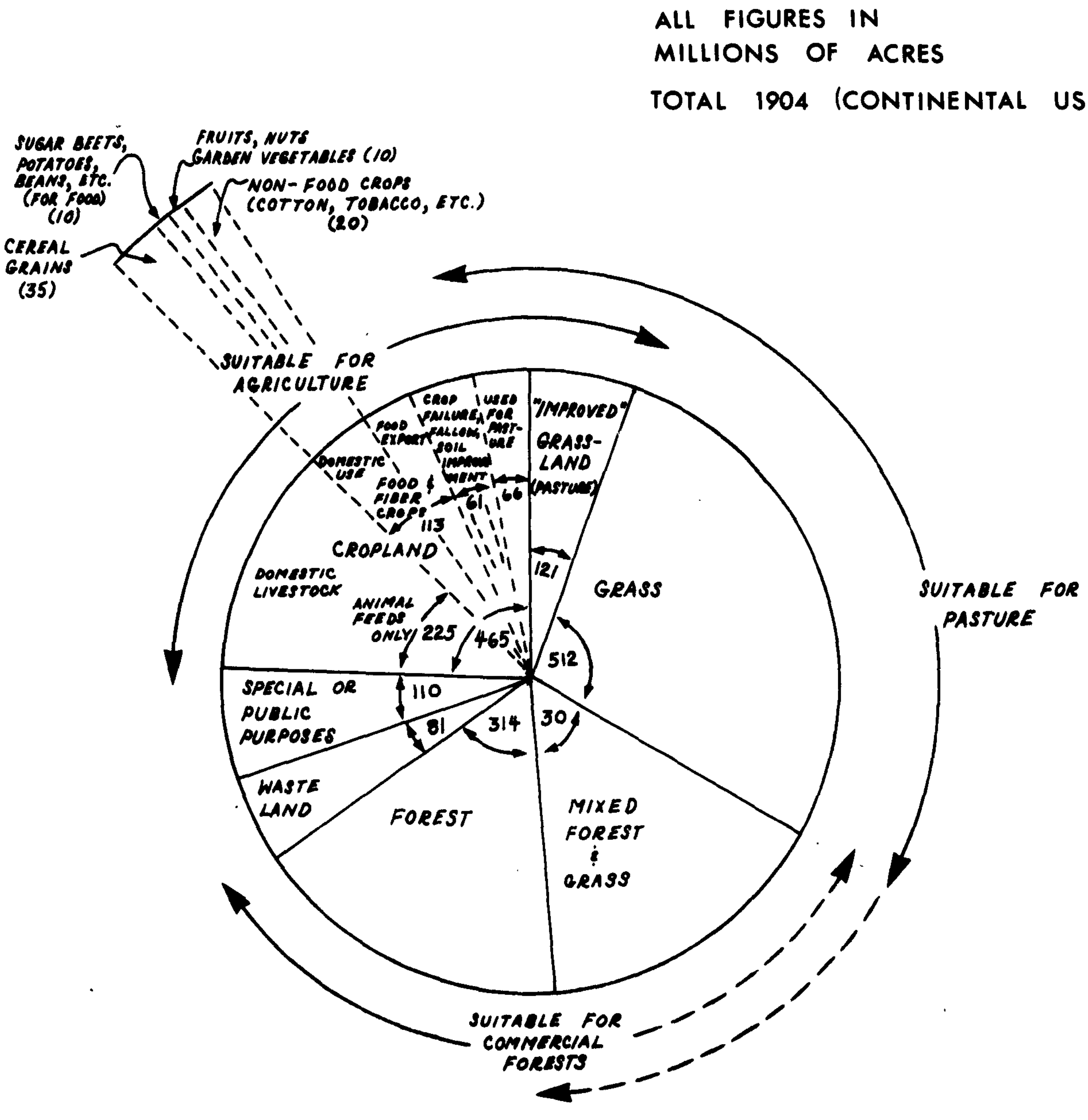

TABLE II- 5

Disposition of Cereal Grain Production (1959) [8]

	Production (1,000 bu)	Acreage Harvested for Grain (1,000 A.)	Seed (1,000 bu)	Processed for Food (1,000 bu)	Feed (1,000 bu)	Miscellaneous*	Exports (1,000 bu)	Human Consumption Total (Mil. bu)	Human Consumption Per Capita (Pounds)
Wheat	1,126,682	52,665	63,733	482,682	49,824	9,131	509,856	482	119 (flour) 2.7 (cereal)
Rye	22,339	1,443	5,707	4,571	7,643	5,536	5,266	4.5	1.2
Rice	53,438 (100 lb. bags)	1,586	2,092 (cwt)	49,831 (cwt)	177 (cwt)		383 (cwt)	884	5.1
Oats	1,066,370	26,368	80,842	42,000 (breakfast food)	1,001,485 (includes other uses & waste)		43,402	40	3.5
Barley	422,073	15,087	24,556	5,500 (malt)	231,624	86,858	118,384	5	1.0
Corn	4,281,316 (total) 3,909,414 (Harvested as grain)	83,529	12,584		3,511,340		210,208	144	7.5 (meal) 1.8 (cereal) 9.9 (sirup) 3.9 (sugar) 1.9 (starch)
Soybeans	533,175 (for beans) 602 (in tons--for hay)	22,487 (beans) 424	29,121		141	401,225 (crushed)	110,072 (net exports)	N.A.	N.A.
Peanuts	1,590,765 (1,000 lb)	1,450	107,130						4.7
Buckwheat	1,233	72	90						

N.A. = negligible amount

* For wheat includes Industrial, military and shipments to Hawaii, Puerto Rico, Guam, Samoa, Virgin Islands & Wake Island. For rye and barley--spirits and alcohol.

TABLE II-6

Quantities of Meat, Poultry, Dairy Produces, Grain Products
Consumed per Capita by Americans
1959*[8]

	Civilian Consumption lbs. per capita (carcass wt.)	Equivalent Pounds of Feed+
Beef and Veal	81.4	870
Lamb and Mutton	4.8	715
Port (excluding lard)	67.6	383
Eggs	352 eggs	197
Chicken	28.9	166
Turkey	6.3	33
Total Milk Products	679.0	740
Fish	10.5	
		3104 (Total)

Direct Human Consumption of Various Commodities in lbs. per Capita:

Sugar	96.4	Wheat: as flour	120.0
Peanuts	4.7	as breakfast cereals	2.7
Potatoes	101.0	Rye: as flour	1.2
Sweet Potatoes	7.4	Total Corn Products	28.0
Dry edible Beans	7.7	(Includes corn meal,	
Rice	5.2	syrup, corn starch,	
Oats	3.5	corn sugar, breakfast	
Barley	1.0	cereal, hominy)	

TABLE II-7

Feed Equivalence of Animal Products

	Weight of Feed Required for 100-pound Weight Gain[8]
Chickens	573
Hogs	571
Beef Cattle (partly grazed, partly grain fed)	1068
Sheep and Lambs (For each 100 pound live-weight production, 18 pound of wool was produced; grain feeds used only for ewes)	1490
Milk (100 lb.)	109
Eggs (100) (Approx. 11 lb. wt. exc. shells)	56

* Figures for 1961 altered somewhat; beef and veal 93.7 lbs., pork 62.2 lbs., eggs 325, etc.

\+ Modification using Table II-7.

Suppose we ask how much of the crop land in the United States would be required to supply a minimal diet based solely on grains and related plant products. Civil defense studies such as the one recently completed by the Hudson Institute[10] have devoted some attention to the problem of supplying elementary diets for limited periods. Here the basic consideration is availability of supplies (in the form of stored surplus grains) which are easily prepared, easily stored and inexpensive. The diet proposed by the Hudson Institute report consisted of 19 ounces of whole grain wheat, steam-toasted; 1½ ounces of dry skimmed milk powder; plus vitamin tablets containing 5,000 USP units of vitamin A, 2½ milligrams of Thiamin (vitamin B_1), 2½ milligrams of riboflavin (vitamin B_2), 20 milligrams of niacin, and 50 milligrams of citamin C.

It would appear that a grain-based diet of approximately 24 ounces per day, or 1½ pounds per day per person, should be a reasonably conservative estimate. This adds up to roughly 550 pounds per capita on a yearly basis for a "Chinese-type" diet. This compares with current per capita consumption of 3300 pounds of food or "feed equivalent": 162 pounds of grain products directly, plus more than 120 pounds of other field and root crops (excluding sugar), plus a feed-equivalent of 3,100 pounds (in the form of animal products). In other words, Americans are today receiving roughly half of their minimum dietary requirements directly from cereal grains, field and root crops, and vegetables (not allowing for losses of food-value due to special methods of cooking, preserving, or processing), which account for only 8% of total plant protoplasm produced on farms.

The crops necessary to supply a total diet of this level can be grown on perhaps 100 million acres (assuming current low-efficiency

methods),* about one-sixth of the land presently considered suitable for large scale agricultural purposes. It is clear that the situation following an attack would have to be quite extreme before a serious over-all food shortage would develop, provided it is still feasible to continue mechanized agriculture.

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*American agriculture is efficient in labor (and dollar) productivity; it is inefficient in land-productivity (see Table II-8). Should the price of labor go down, still more land (perhaps 25-30%) could be brought under cultivation.

TABLE II-8[11]

	Cultivated acres/person	Calories per Cultivated Acre per day
Canada	5.4	North America 2500
Australia	5.3	Western Europe 7500
Argentine	3.7	Latin America 4700
United States	2.7	4500
U.S.S.R.	2.6	2300
India	0.8	2500
Germany	0.4	
China	0.3	(Asia) 4000
United Kingdom	0.3	
Japan	0.2	13,200

<u>Crop Distribution</u>[12] Theoretically, and partly in practice, the distribution of crops is determined by maximizing the dollar-yield of each acre of land. The dollar-yield of course depends upon the productivity of the land in the chosen crop, the price of that crop and the cost of production and distribution. Since price does not vary from area to area (if transport costs and production costs are lumped together), the main factor determining the farmer's choice of one crop over another (given the land and labor he has to work with) is the ecological "fit." In other words, the choice will be made in terms of which crop is best adapted to the soil and climate (of the various marketable alternatives). This does not mean that crops tend to be grown where they are best adapted. The best a farmer can do is find the optimum crop for his farm, not the optimum conditions for the chosen crop--which are generally not available. However, as a rule the optimum crop for one farm is also the optimum crop for the other farms nearby. Hence the principal crops are found in distinct regions, as can be seen in the crop distribution maps in Annex A. Table II-9 gives production figures for selected crops comparing the world average with the area of optimum ecological conditions.

TABLE II-9[13]

	Net primary production grams/sq. meter/day				
	World Average		Area of Highest Yield		Area of optimum ecological conditions
	Year round	Growing season	Year round	Growing season	
Wheat	0.94	2.3	3.43	8.3	Netherlands
Oats	0.98	2.4	2.54	6.2	Denmark
Corn	1.13	2.3	2.77	5.6	Illinois
Rice	1.36	2.7	3.95	8.0	Italy and Japan
Hay (U.S.)	1.15	2.3	2.58	5.2	California
Potatoes	1.10	2.6	2.31	5.6	Netherlands
Sugar cane	4.73	4.7	9.40	9.4	Hawaii

Among the most critical of the "other necessities" would be drugs. A number of important hormones are obtained from animal glands (e.g. thyroid extract, cortisone and ACTH, and insulin). If most livestock were killed by a heavy thermonuclear attack there would be no substitute for these. A small part of the population could be immediately affected, (mainly diabetics).

Another important group of biologically derived drugs are the anti-biotics, anti-toxins and vaccines. Here the danger is not so much to the organisms which produce the drugs as to the capacity required.* Production of vaccines also requires animals as intermediaries, e.g., cows for small-pox, horses for tetanus, chick embryos for polio, guinea pigs for diptheria, etc. A glance at the fallout maps gives an indication of the vulnerability of the U.S. drug industry.

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*The most important members of the current arsenal of anti-biotics are the tetracyclines, chloramphenicol, (Chloromycetin), and erythromycin. Total U.S. production of these comes from only eight plants located in Brooklyn, N.Y., Pearl River (Rockland County), N.Y., Syracuse, N.Y., King of Prussia, Pa. (outside Philadelphia), Detroit, Michigan, Kalamazoo, Michigan, Indianapolis, Indiana, and Chicago. The two chief producers of vaccines (smallpox, tetanus, typhoid-paratyphoid, plague and cholera) are in Indianapolis and Berkeley, California.[14]

Crop Sensitivities to Fallout Radiation

In section §3 of Chapter I some scattered material on basic radio-sensitivities of plants was collected. It was pointed out that one of the crucial questions which arises in this connection is the relative degree of "exposure" of the various plants, especially to β-radiation, inasmuch as the latter is potentially very damaging to surface tissues. Whereas the exposure of plants in a given locale is likely to more or less uniform, determined by the local fallout density, the β-exposure will depend very much on the configuration of the plant. Furthermore, in evaluating the relative likelihood of radiation damage to the plant cover as a whole, the life cycle of the plants must be taken into account. Plants in North America are divided conveniently as follows:

Virtually all familiar forest evergreens belong to the family Pinaceae of the order Coniferae. These are gymnosperms.

All of the following are angiosperms:

The most important food crops belong to grass family (Gramineae), of the subclass monocotylae. These are non-woody, and may be annual or perennial. Perennial grasses die back to ground level each season, and grow from root-stock as well as seeds. This group includes corn, sugar-cane, rice and all the cereal grains. All other food crops of any consequence belong to subclass dicotylae:

Next in order of importance are the legume family (Papilionaceae) including dry beans of all kinds, peas, alfalfa, clover, vetch, etc. The important ones are annuals.

The principal vegetable groups are the cabbage family (Cruciferae) including cabbage, brussel sprouts, cauliflower, broccoli, kale, turnip (all members of the genus Brassica); the melon family (cucurbitae) including melons, cucumbers, squash, pumpkin, etc.; the lettuce family (Compositae) including lettuce and artichoke, etc; the family (Umbelliferae) including carrots, parsley, parsnip and celery; the family (Chenopodiaceae) including spinach, chard, beets and sugar beets; the family (Solanaceae) including the potato, tomato, tobacco and several plants of medical importance.* Most plants in these groups are annuals or biennials.

Most temperate climate fruits and berries belong to the family Rosaceae. These are mostly trees, except the berries which propogate each year from roots. Citrus fruits belong to the genus Citrus, family Rutaceae. Grapes belong to the family Vitaceae.

Most deciduous forest trees (except conifers) belong to the families Betulaceae (softwoods, including birch, alden, hazel, etc.). Fagaceae, (hardwoods, including beech, oak, chestnut, etc.), the maple family (Aceraceae) and the walnut-hickory family (Juglandaceae).

Note that virtually all of the economically important higher plants+ belong to only 16 families of the hundreds identified. Perhaps 5 families could properly be called crucial.⊥ Within each family there is a certain degree of similarity. In some cases the similarity is on the generic level.

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*This group of plants yields a number of alkaloids: atropine, hyoscine, nicotine and digitalis among others.

+Excluding the tropics.

⊥Possibly grasses, legumes, potatoes, conifers, and oak-beech hardwoods.

It has been pointed out already (Chapter I section §3) that plants in the first two categories, gymnosperms and monocots, tend (on a statistical basis) to have larger nuclei than the dicots. The following additional remarks can be made:

(i) Large woody species (e.g. trees) are likely to be relatively less subject to damage from the β-component in fallout than smaller plants with exposed meristems, due to the thickness of the protective outer layers of tissue.

(ii) Plants having large surface area/volume ratios will be relatively more susceptible to β-damage. In particular, the cross-sectional area exposed to the zenith is important. Thus spiky, narrow-leaved plants (e.g. grasses) offer less available surface than broad-leaved plants (e.g. members of the cabbage family). Thick-leaved plants may be less susceptible than thin-leaved plants. Downturned leaves or flowers are less likely to catch and hold fallout material than upturned ones.

(iii) Consequences of γ or β damage to herbaceous perennials would be temporary, since plants die back to the ground each season anyway. Consequences to herbaceous annuals would be equally temporary provided seed, labor, etc. were available for the following year's planting. In the case of woody perennials damage would have more lasting results, depending on the rate of growth.

Altogether, the relative likelihood of immediate and long-term damage (assuming equal intrinsic sensitivity of the meristems*) for various classes of plants would probably be:

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*In the absence of real comparative data.

TABLE II-10

Rank Order of Likelihood of β-Damage

1.	Broad leaves; herbaceous	Cabbage family Lettuce family Spinach-beet family Melon family	Quite likely
2.	Intermediate leaves; herbaceous	Potato-tomato family Legumes	Moderately likely
3.	Narrow leaves; herbaceous	Carrot family Grasses	
4.	Broad leaves, woody Trees, deciduous broad, inter-mediate leaves; woody	Grapes Fruit-nut Citrus Deciduous forest-types (2 families)	Unlikely
5.	Trees, evergreen needles; woody	Conifers	Very unlikely

§3 Possible Simplified Postattack Ecostystems and Synthetic Sources.

Recent research, some of which has been directed towards considerations relating to producing a self-supporting biological environment which could be sent into outer space, but which might be equally applied to shelters, or other restricted circumstances, has directed attention to certain possibilities of closed ecosystems in which man and certain other organisms are in equilibrium. These results are interesting insofar as they indicate the limits of present day capabilities. We quote from one description of such a system:[15]

> In this system one is presented, in so intimate a fashion as to be aesthetically discouraging, a miniaturized version of the events taking place in the macrocosm. Man eats food; food residues--gaseous, fluid and solid--are more or less converted into plant food; plants grow and produce oxygen; man eats plants and breathes oxygen; and so it goes.

The simplest system is to cultivate some simple green single-celled algae such as Chlorella. Five pounds of the alga Chlorella pyrenoidosa produces sufficient oxygen for a man.[16] Algae range from 50-70% protein, plus some vitamin A, B-complex, and a little C. Unfortunately algae are generally hard to digest and also tend to be mildly deficient in the amino acids, methionine and histidine, and grossly deficient in cystine.[17] A more important practical difficulty is that alga-culture is still in the experimental stage.

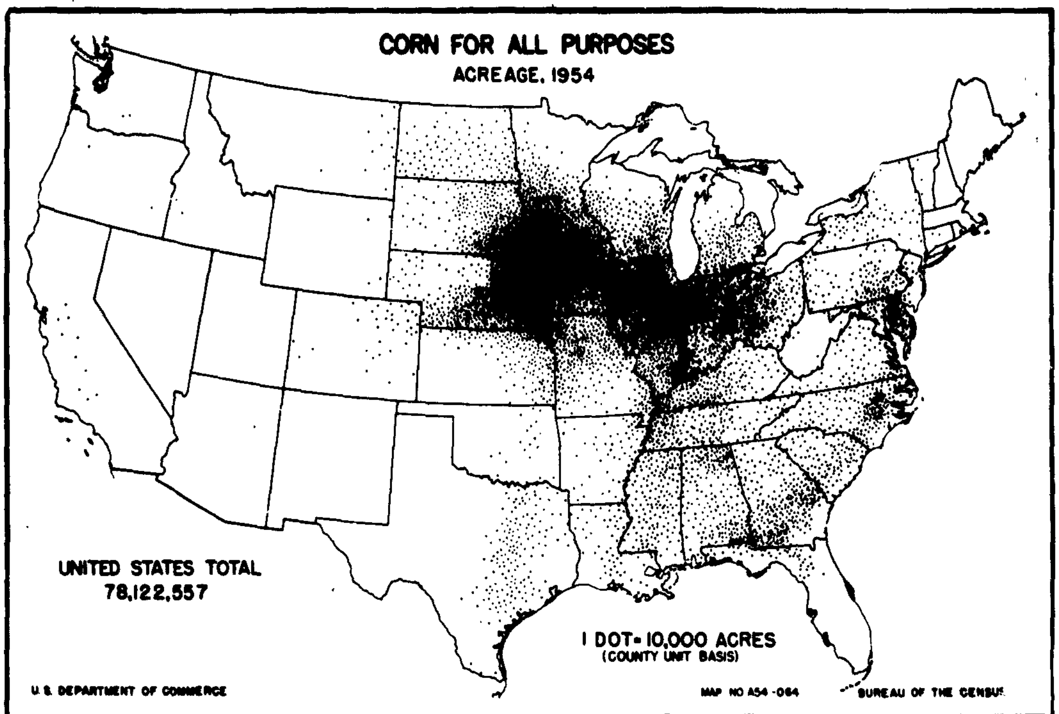
Yeasts are an alternative food source. Like algae, they are approximately 50% protein by weight and very rich sources of all the B vitamins

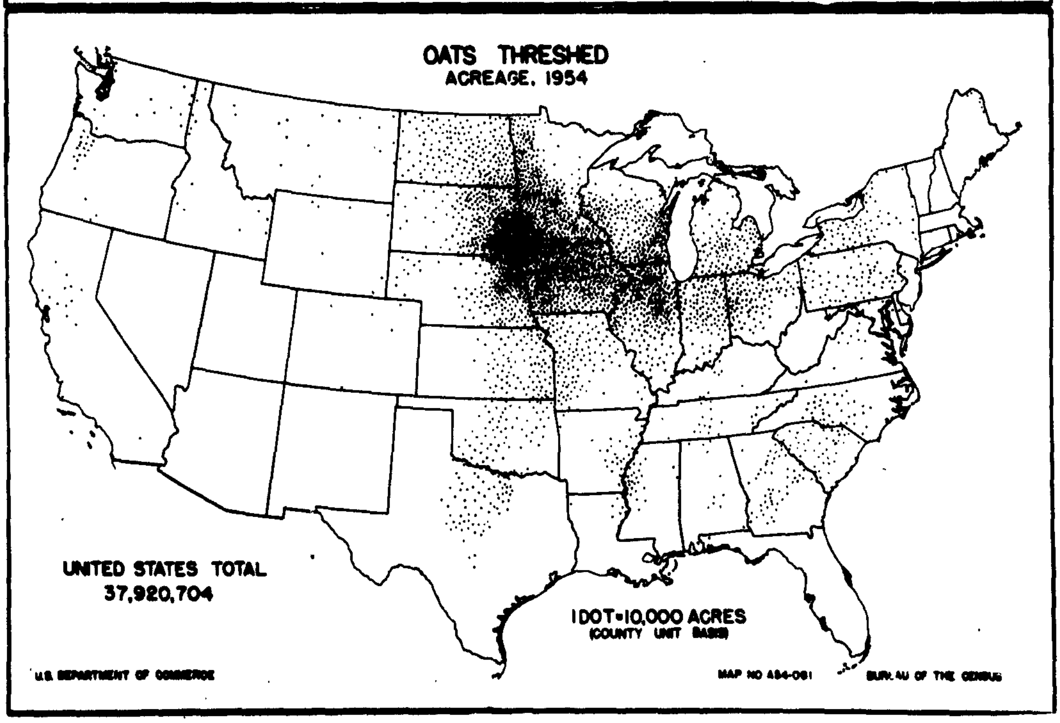
(but not vitamin A or C). Yeasts can be grown in aqueous solutions of various organic sugars, particularly glucose and sucrose, which in turn can be produced from starch or raw cellulose by a very easy chemical process (e.g. boiling in dilute acid). Unfortunately yeast is also low in the sulfur-containing amino acids (cystine and methionine).

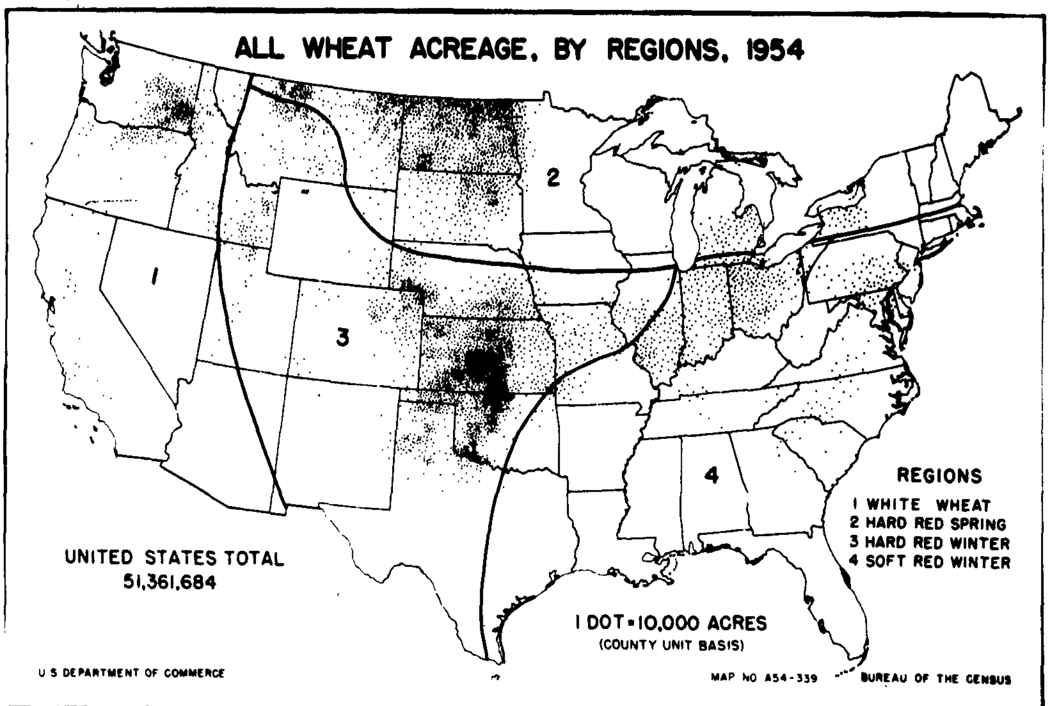
It is possibly worth mentioning at this point that protein may be obtainable in the future by cultivating micro-organisms in crude petroleum.[18] Oil companies searching for new markets have discovered that it is possible to feed certain heavy, otherwise undesirable hydrocarbon fractions to micro-organisms which will produce a concentrated protein. In principle, it can be produced in enormous quantities at a very low cost.

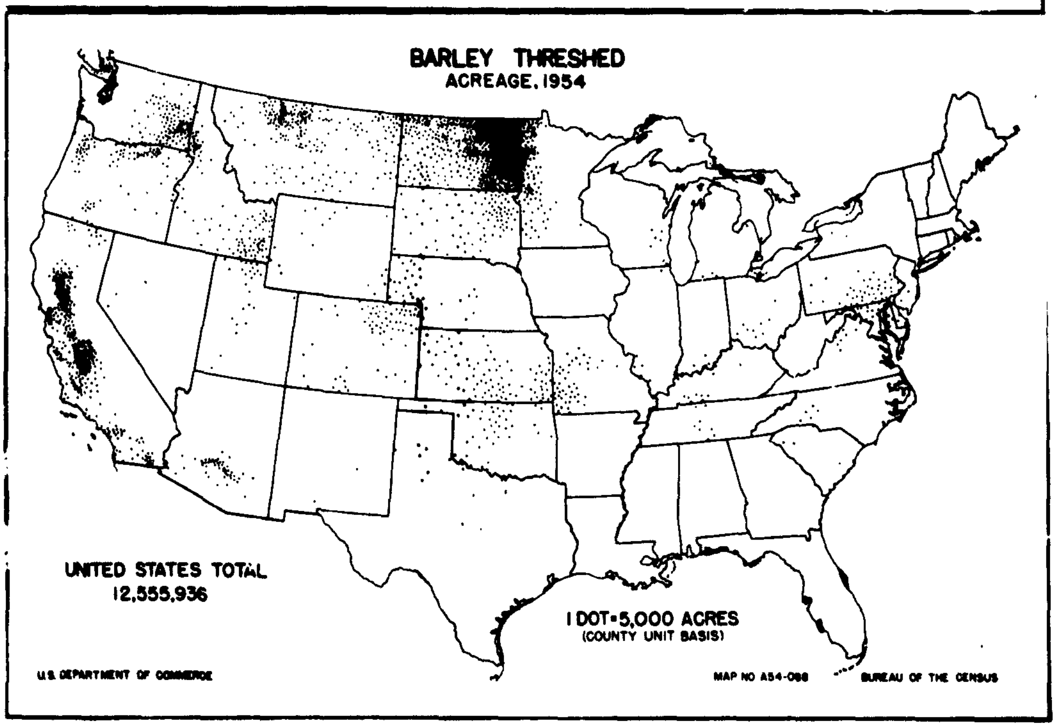
ANNEX A

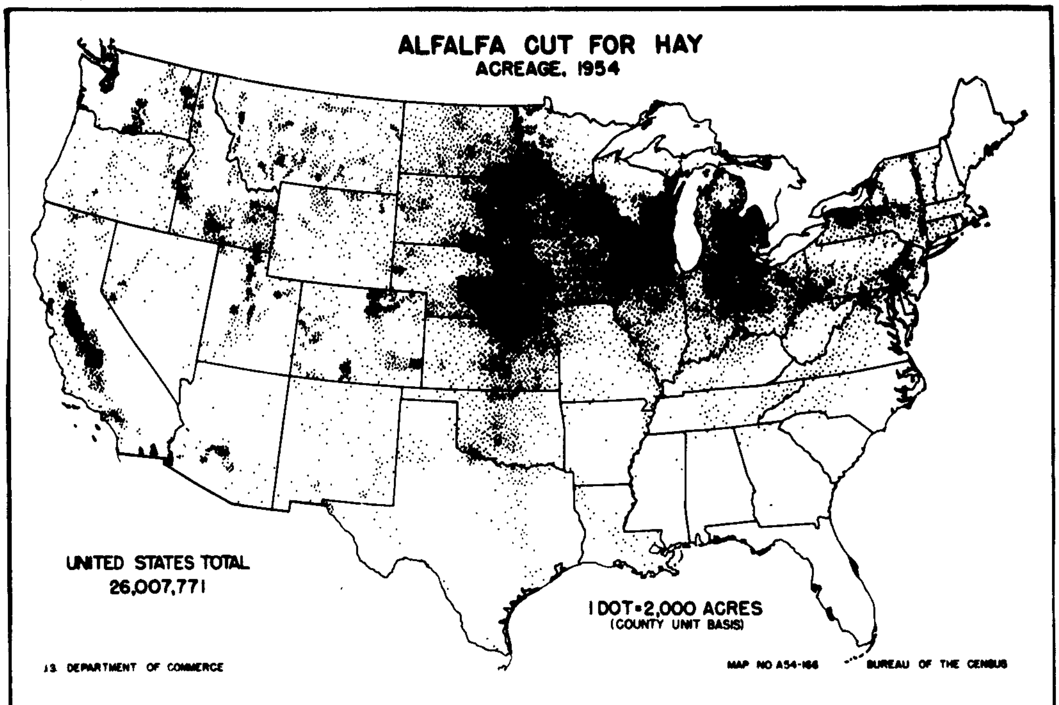
(to Chapter II § 3)

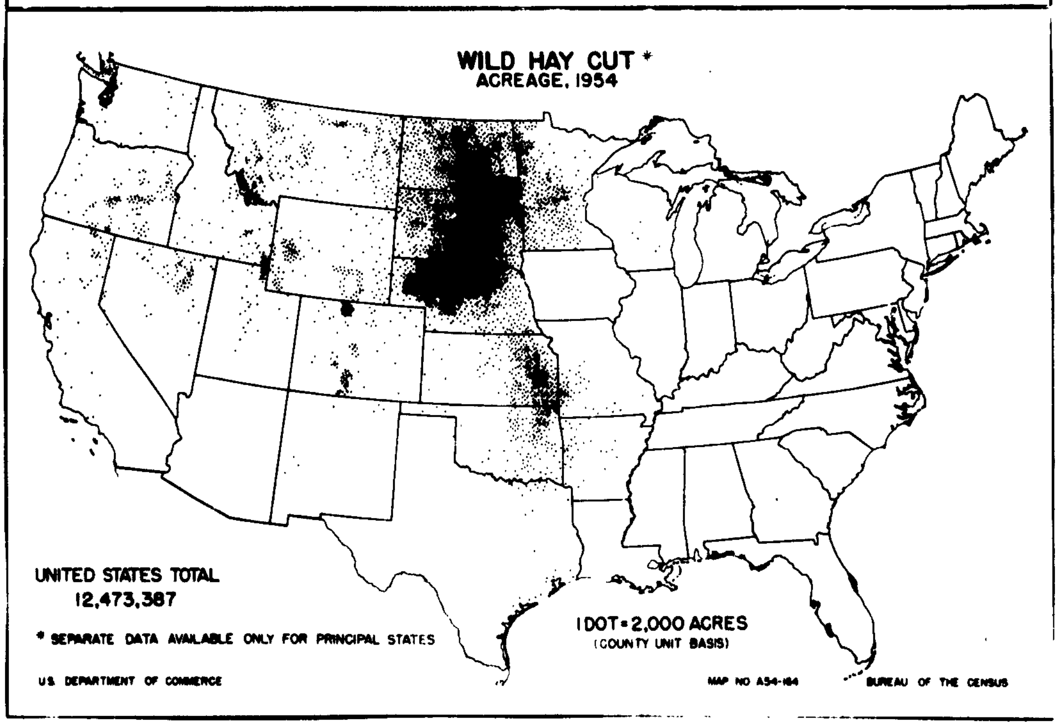

CORN FOR ALL PURPOSES
ACREAGE, 1954
UNITED STATES TOTAL
78,122,557
1 DOT = 10,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-064

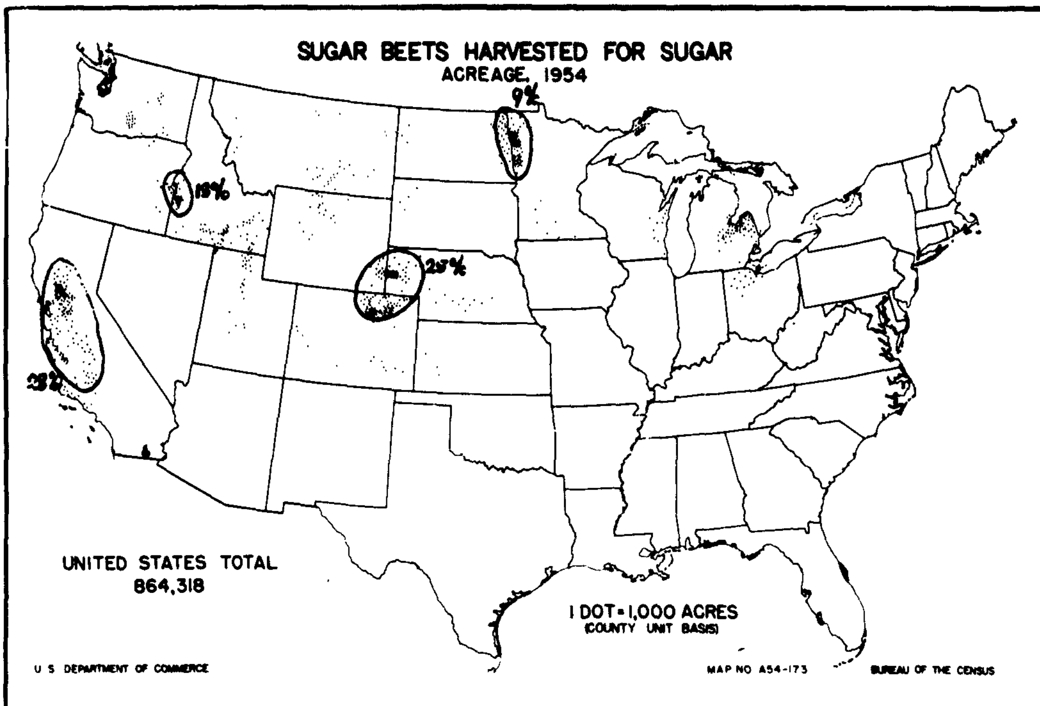

OATS THRESHED
ACREAGE, 1954
UNITED STATES TOTAL
37,920,704
1 DOT = 10,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-061

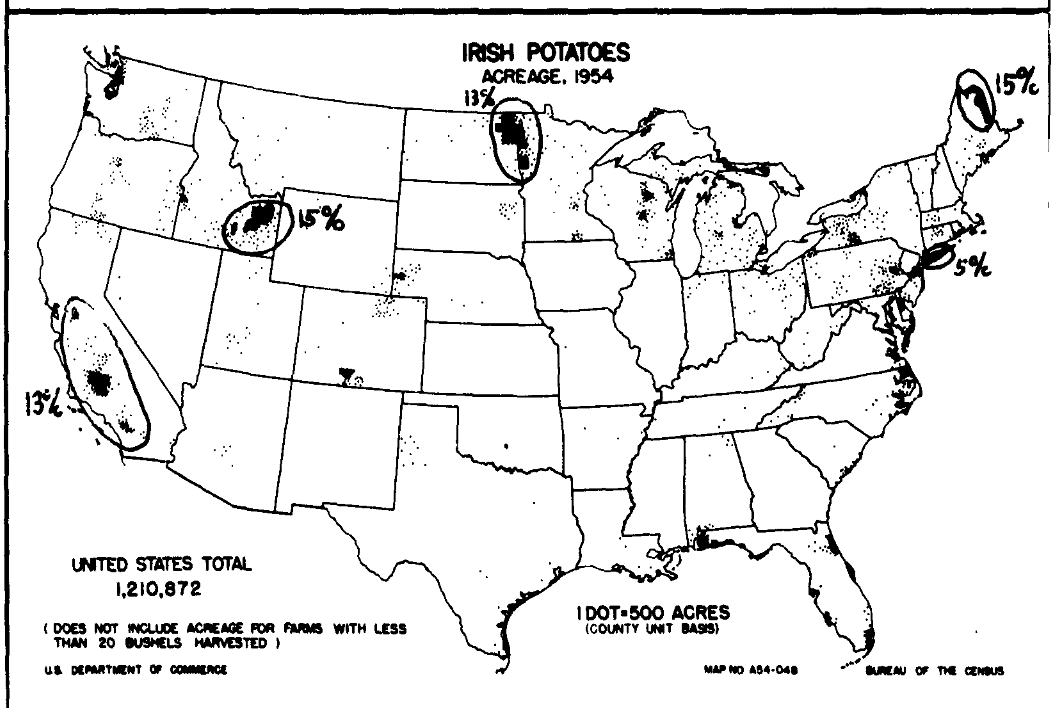

ALL WHEAT ACREAGE, BY REGIONS, 1954
1
2
3
4
REGIONS
1 WHITE WHEAT
2 HARD RED SPRING
3 HARD RED WINTER
4 SOFT RED WINTER
UNITED STATES TOTAL
51,361,684
1 DOT = 10,000 ACRES
(COUNTY UNIT BASIS)
U S DEPARTMENT OF COMMERCE
MAP NO A54-339
BUREAU OF THE CENSUS

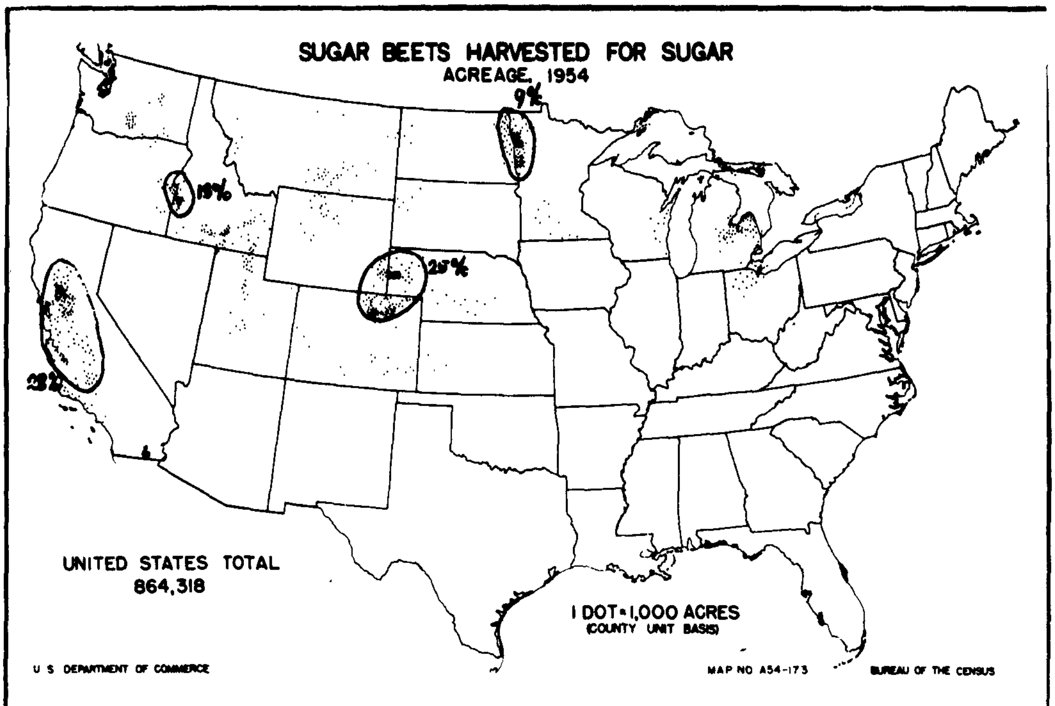

BARLEY THRESHED
ACREAGE, 1954
UNITED STATES TOTAL
12,555,936
1 DOT = 5,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-088
BUREAU OF THE CENSUS

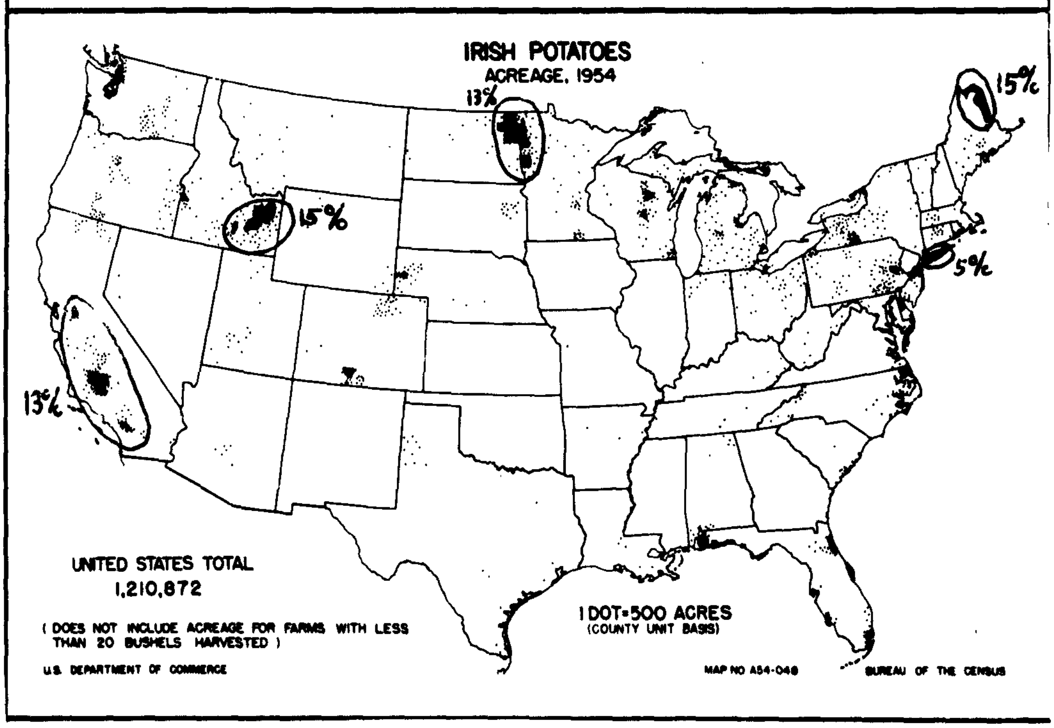

ALFALFA CUT FOR HAY
ACREAGE, 1954
UNITED STATES TOTAL
26,007,771
1 DOT = 2,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-166
BUREAU OF THE CENSUS

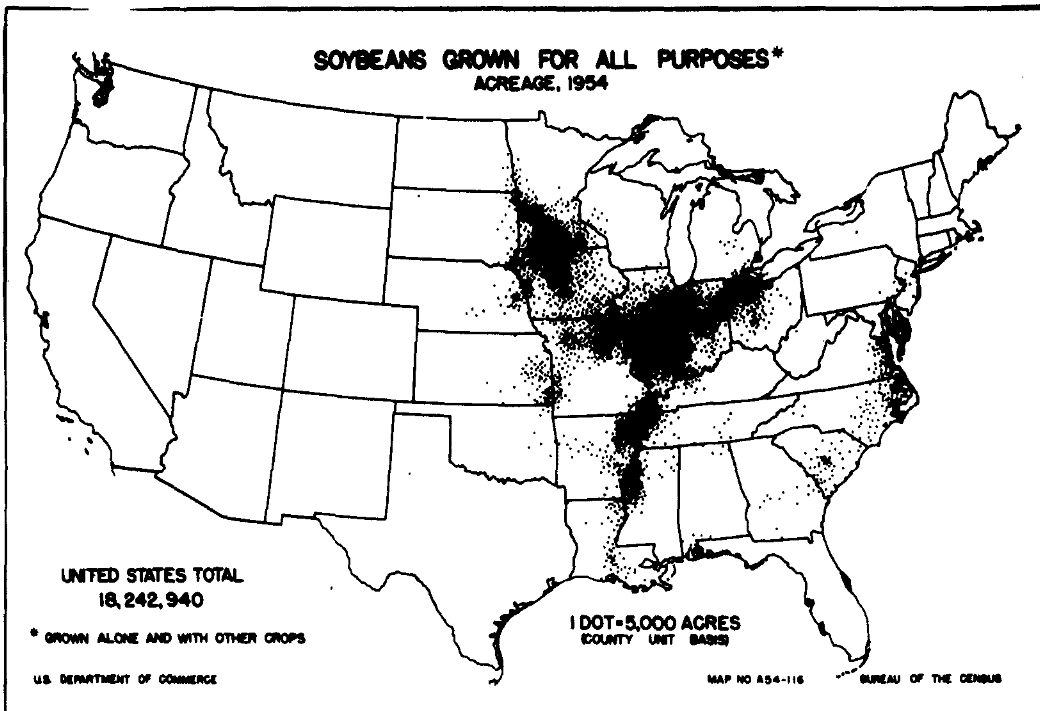

WILD HAY CUT *
ACREAGE, 1954
UNITED STATES TOTAL
12,473,387
* SEPARATE DATA AVAILABLE ONLY FOR PRINCIPAL STATES
1 DOT = 2,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-164
BUREAU OF THE CENSUS

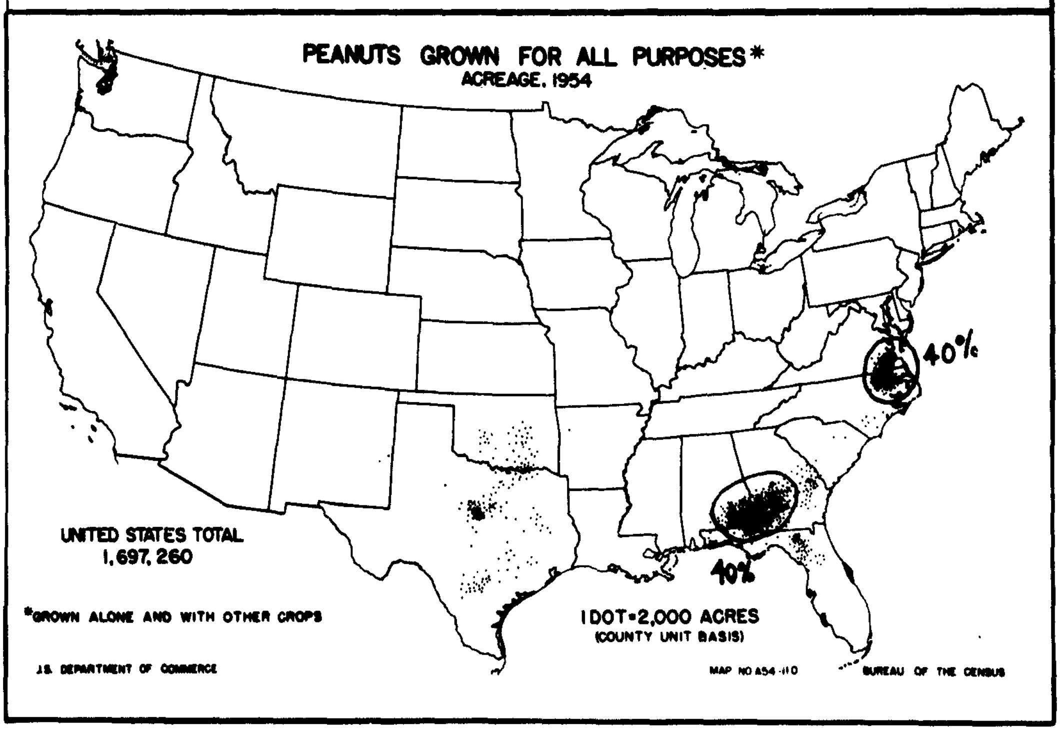

SUGAR BEETS HARVESTED FOR SUGAR
ACREAGE, 1954
9%
18%
23%
UNITED STATES TOTAL
864,318
I DOT = 1,000 ACRES
(COUNTY UNIT BASIS)
U S DEPARTMENT OF COMMERCE
MAP NO A54-173
BUREAU OF THE CENSUS

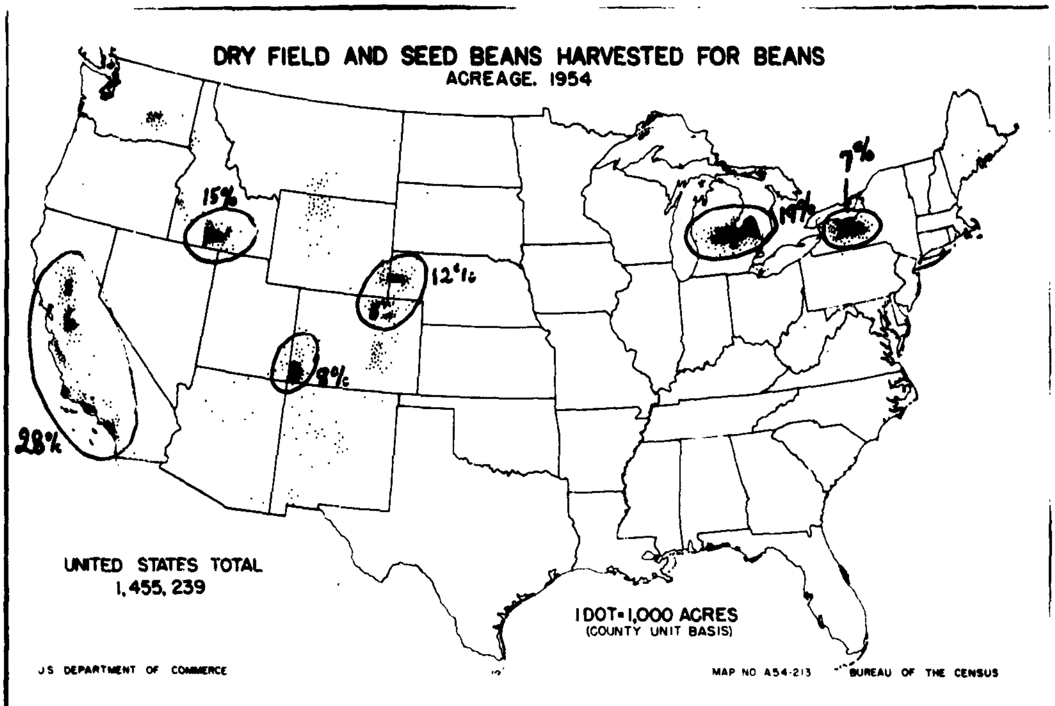

IRISH POTATOES
ACREAGE, 1954
13%
15%
15%
5%
13%
UNITED STATES TOTAL
1,210,872
(DOES NOT INCLUDE ACREAGE FOR FARMS WITH LESS THAN 20 BUSHELS HARVESTED)
I DOT = 500 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-048
BUREAU OF THE CENSUS

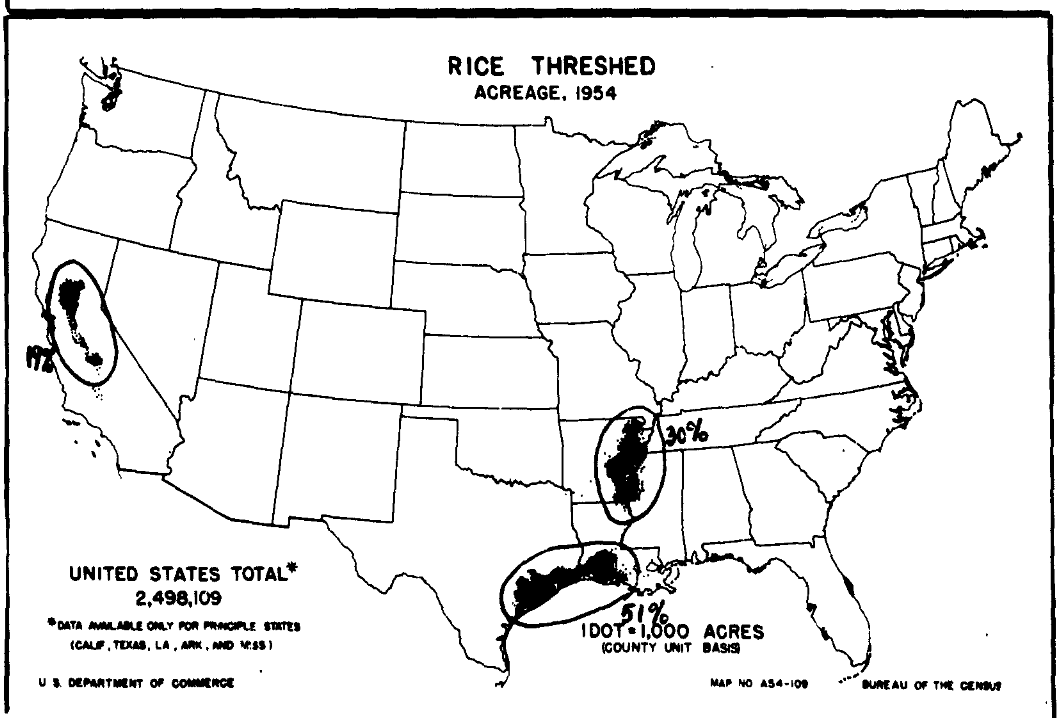

SUGAR BEETS HARVESTED FOR SUGAR
ACREAGE, 1954
9%
UNITED STATES TOTAL
864,318
1 DOT = 1,000 ACRES
(COUNTY UNIT BASIS)
U S DEPARTMENT OF COMMERCE
MAP NO A54-173
BUREAU OF THE CENSUS

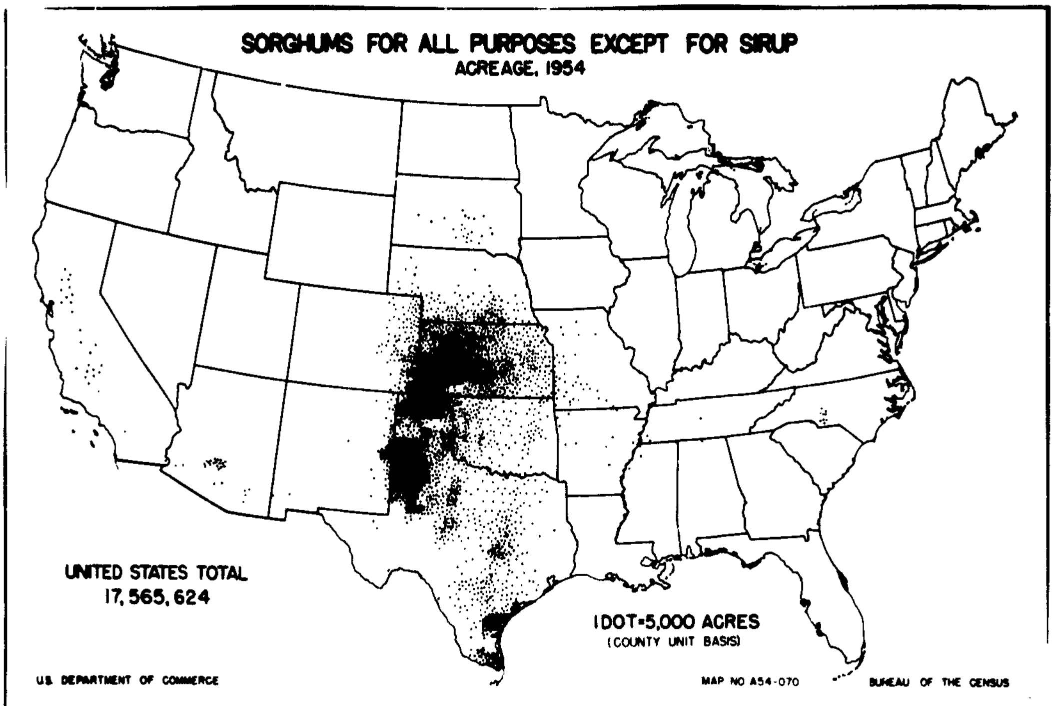

IRISH POTATOES
ACREAGE, 1954
13%
15%
15%
5%
13%
UNITED STATES TOTAL
1,210,872
(DOES NOT INCLUDE ACREAGE FOR FARMS WITH LESS THAN 20 BUSHELS HARVESTED)
1 DOT = 500 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-048
BUREAU OF THE CENSUS

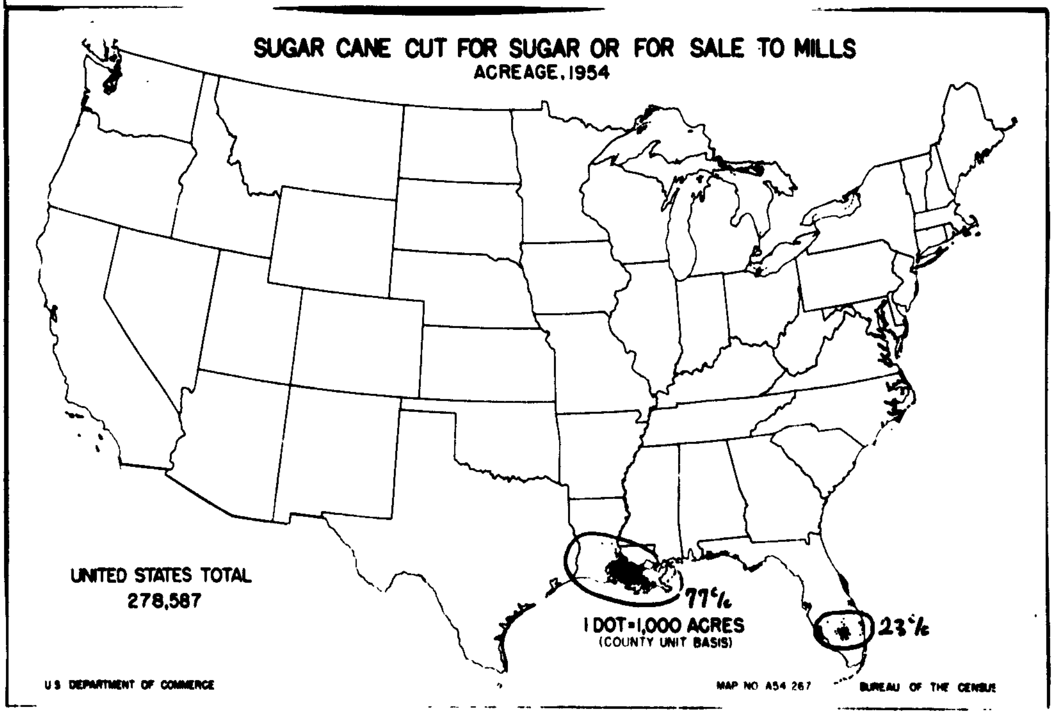

SOYBEANS GROWN FOR ALL PURPOSES*
ACREAGE, 1954
UNITED STATES TOTAL
18,242,940
* GROWN ALONE AND WITH OTHER CROPS
1 DOT=5,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-116
BUREAU OF THE CENSUS

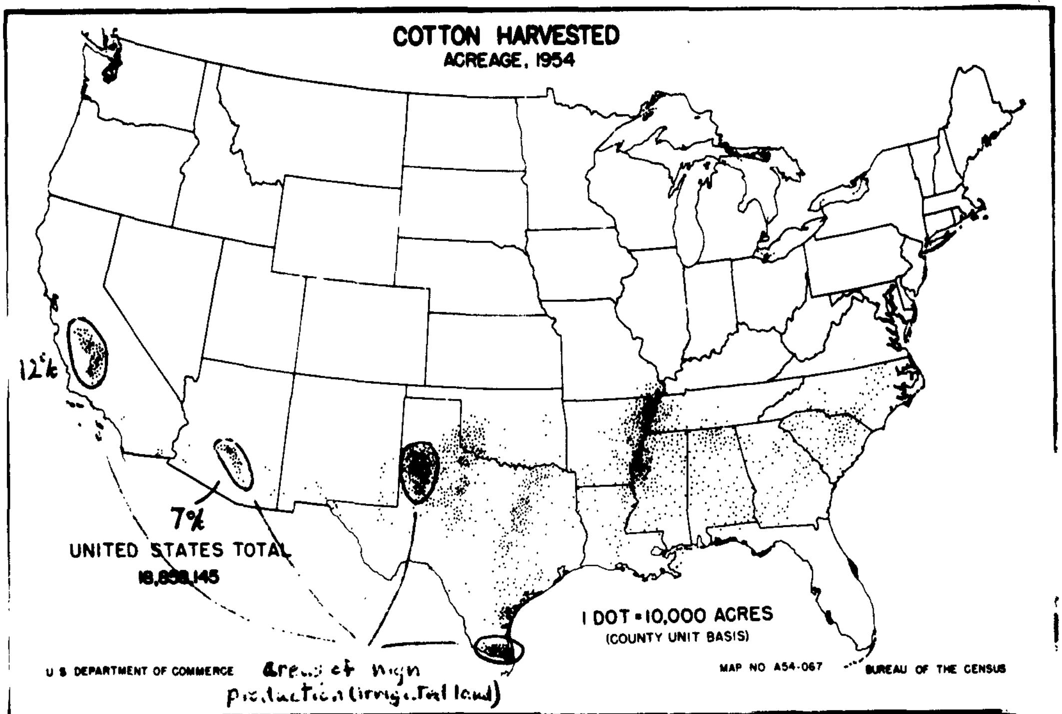

PEANUTS GROWN FOR ALL PURPOSES*
ACREAGE, 1954
40%
40%
UNITED STATES TOTAL
1,697,260
*GROWN ALONE AND WITH OTHER CROPS
1 DOT=2,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-110
BUREAU OF THE CENSUS

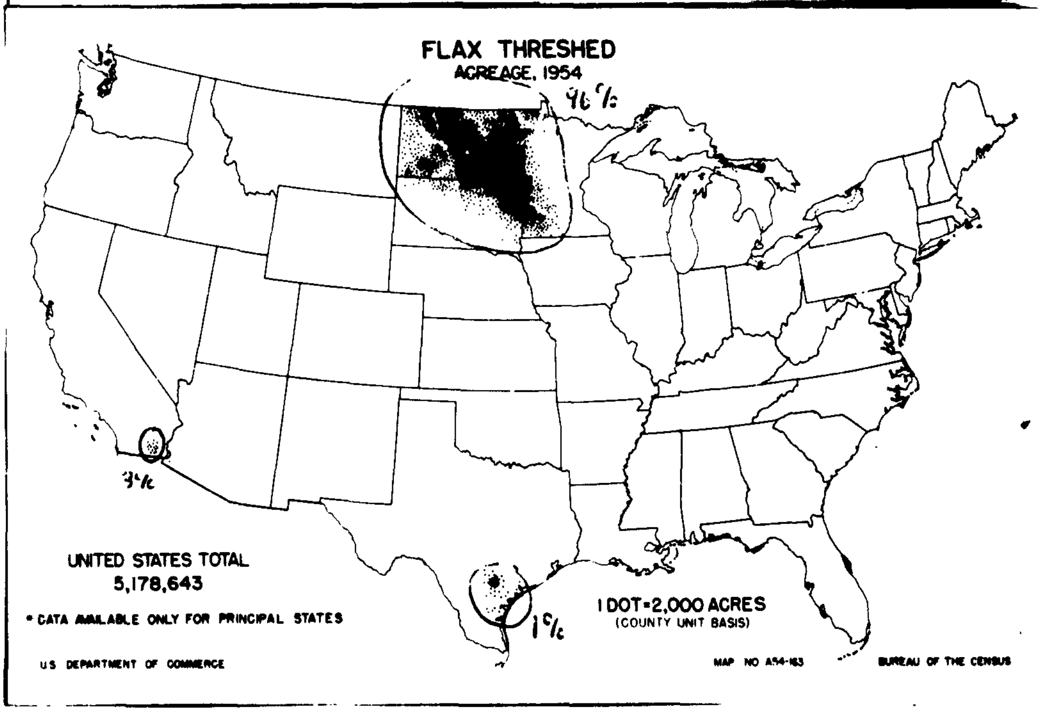

DRY FIELD AND SEED BEANS HARVESTED FOR BEANS
ACREAGE, 1954
15%
12%
9%
28%
19%
7%
UNITED STATES TOTAL
1,455,239
1 DOT=1,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-213
BUREAU OF THE CENSUS

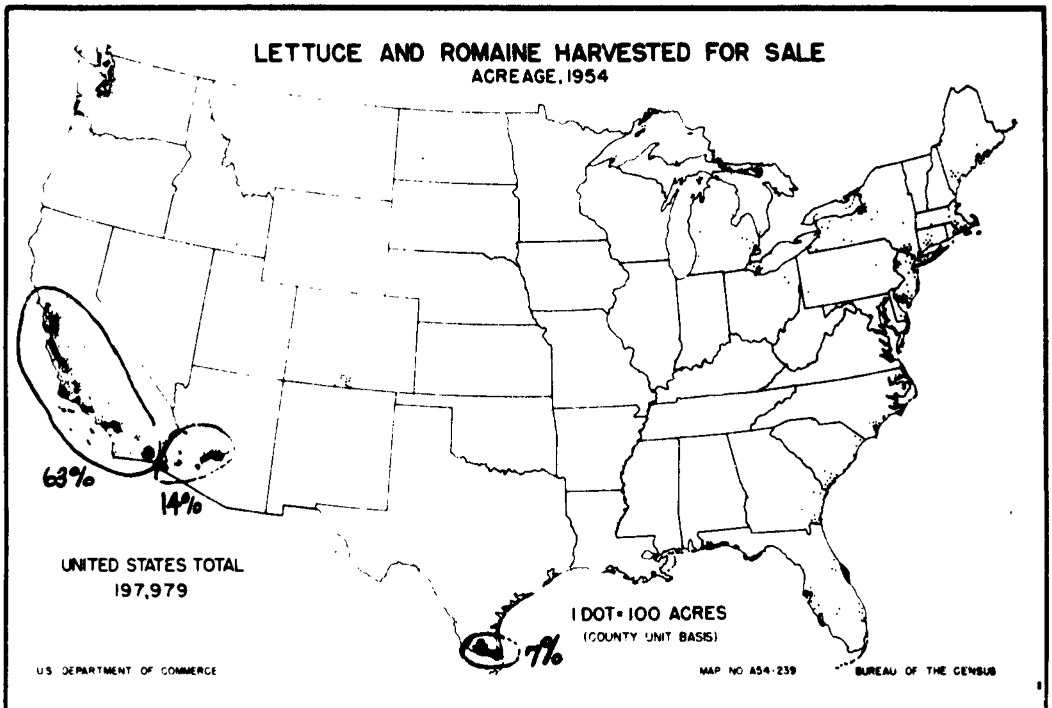

RICE THRESHED
ACREAGE, 1954
19%
30%
51%
UNITED STATES TOTAL*
2,498,109
*DATA AVAILABLE ONLY FOR PRINCIPLE STATES
(CALIF., TEXAS, LA., ARK., AND MISS.)
1 DOT=1,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO A54-109
BUREAU OF THE CENSUS

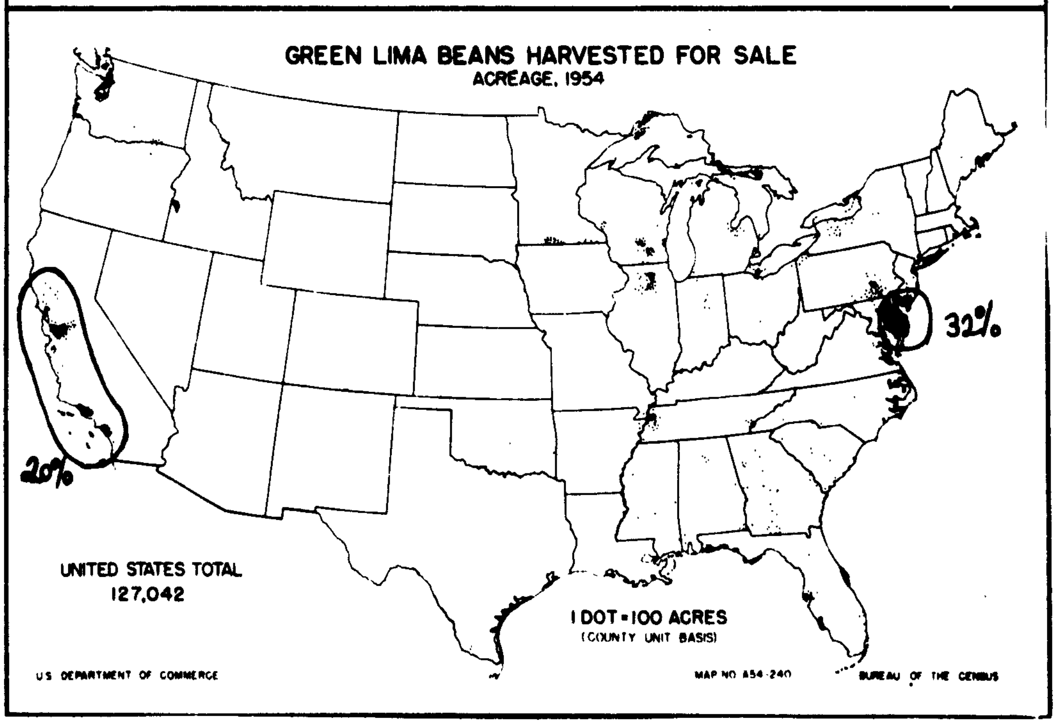

SORGHUMS FOR ALL PURPOSES EXCEPT FOR SIRUP
ACREAGE, 1954
UNITED STATES TOTAL
17,565,624
1 DOT=5,000 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54-070
BUREAU OF THE CENSUS

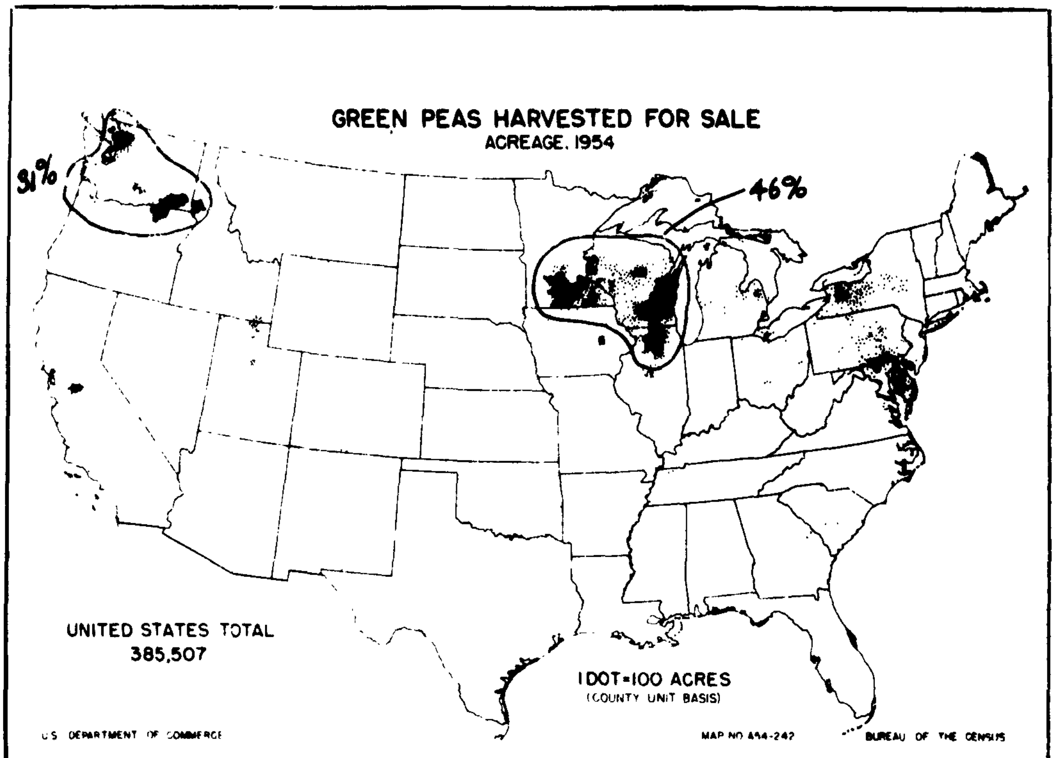

SUGAR CANE CUT FOR SUGAR OR FOR SALE TO MILLS
ACREAGE, 1954
UNITED STATES TOTAL
278,587
77%
1 DOT=1,000 ACRES
(COUNTY UNIT BASIS)
23%
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54 267
BUREAU OF THE CENSUS


COTTON HARVESTED
ACREAGE, 1954
12%
7%
UNITED STATES TOTAL
18,858,145
1 DOT = 10,000 ACRES
(COUNTY UNIT BASIS)
U S DEPARTMENT OF COMMERCE
areas of high production (irrigated land)
MAP NO A54-067
BUREAU OF THE CENSUS

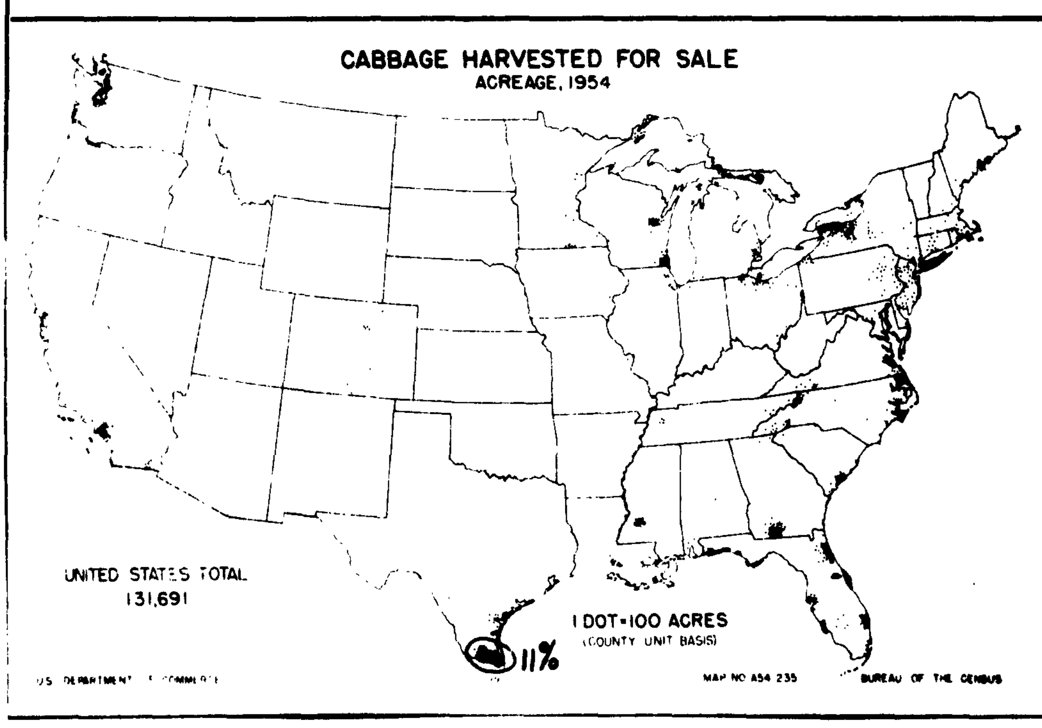

FLAX THRESHED
ACREAGE, 1954
96%
3%
UNITED STATES TOTAL
5,178,643
* DATA AVAILABLE ONLY FOR PRINCIPAL STATES
1%
1 DOT = 2,000 ACRES
(COUNTY UNIT BASIS)
U S DEPARTMENT OF COMMERCE
MAP NO A54-163
BUREAU OF THE CENSUS


LETTUCE AND ROMAINE HARVESTED FOR SALE
ACREAGE, 1954
63%
14%
7%
UNITED STATES TOTAL
197,979
I DOT = 100 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54-239
BUREAU OF THE CENSUS

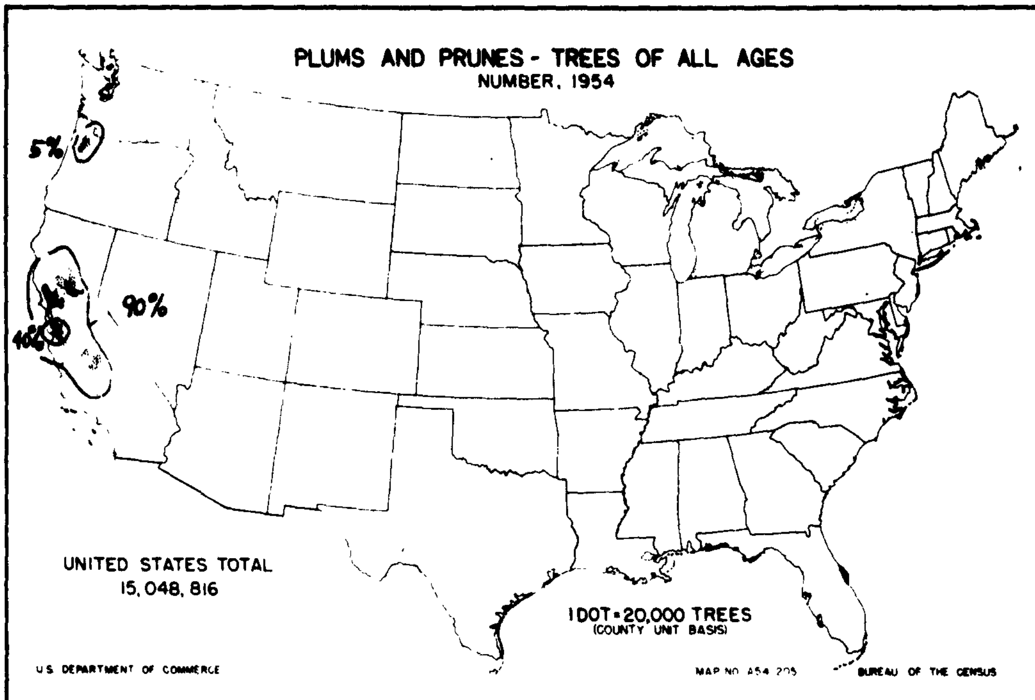

GREEN LIMA BEANS HARVESTED FOR SALE
ACREAGE, 1954
20%
32%
UNITED STATES TOTAL
127,042
I DOT = 100 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54-240
BUREAU OF THE CENSUS

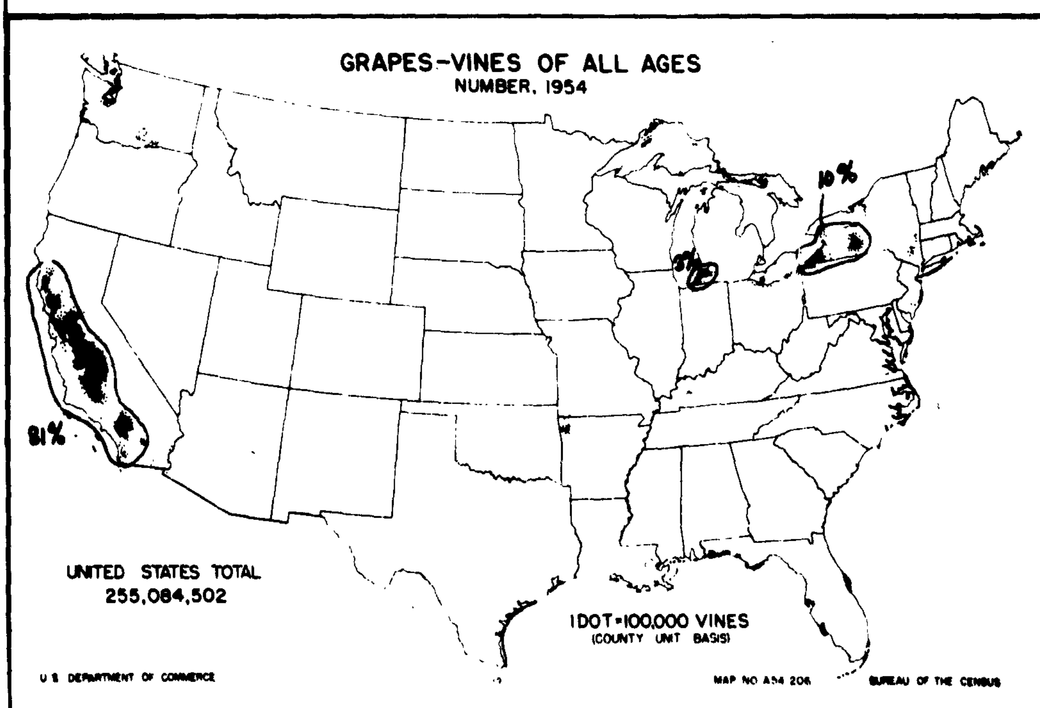


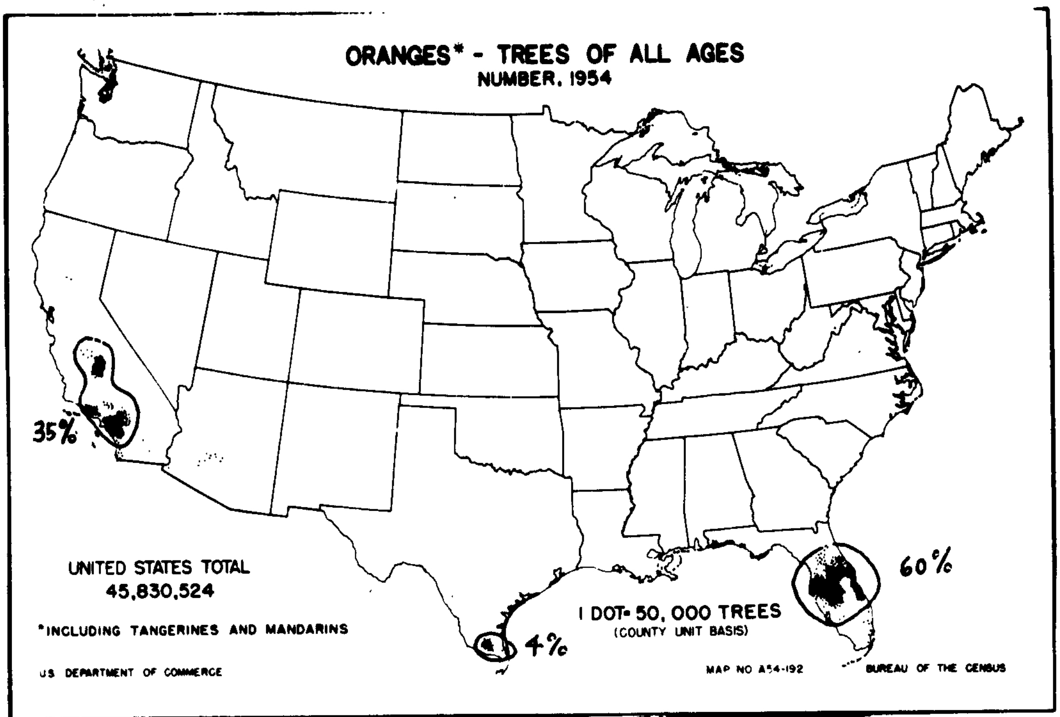
GREEN PEAS HARVESTED FOR SALE
ACREAGE, 1954
31%
46%
UNITED STATES TOTAL
385,507
1 DOT=100 ACRES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54-242
BUREAU OF THE CENSUS

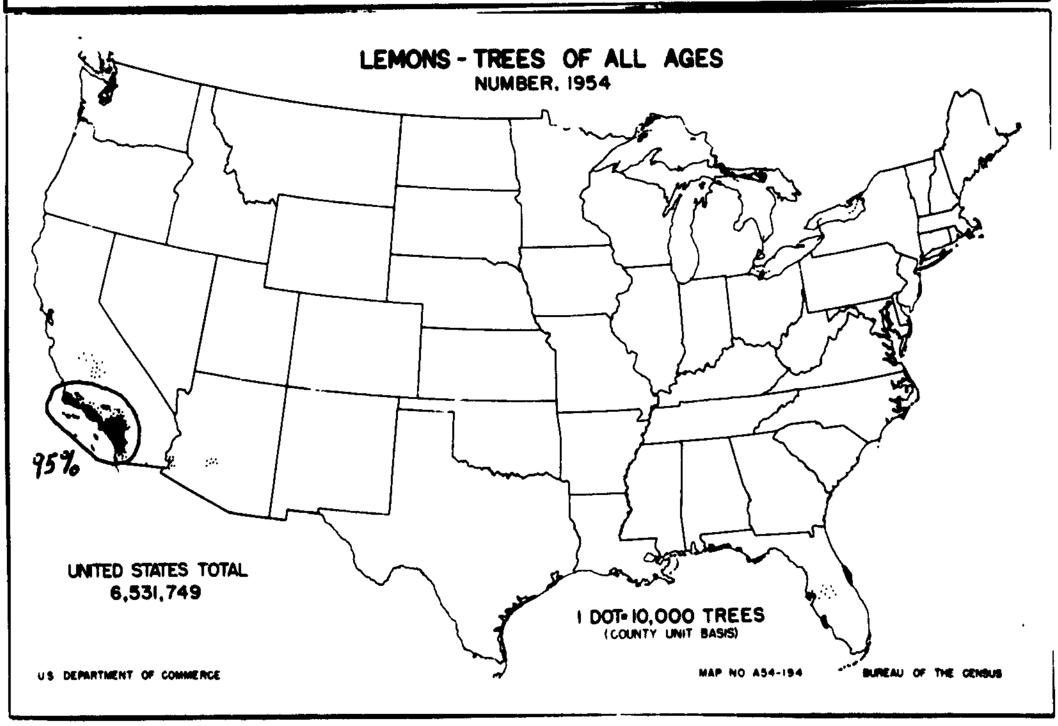


CABBAGE HARVESTED FOR SALE
ACREAGE, 1954
UNITED STATES TOTAL
131,691
1 DOT=100 ACRES
(COUNTY UNIT BASIS)
11%
MAP NO. A54-235
BUREAU OF THE CENSUS


PLUMS AND PRUNES - TREES OF ALL AGES
NUMBER, 1954
5%
90%
40%
UNITED STATES TOTAL
15,048,816
1 DOT = 20,000 TREES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54-205
BUREAU OF THE CENSUS


GRAPES-VINES OF ALL AGES
NUMBER, 1954
10%
3%
81%
UNITED STATES TOTAL
255,084,502
1 DOT = 100,000 VINES
(COUNTY UNIT BASIS)
U.S. DEPARTMENT OF COMMERCE
MAP NO. A54-206
BUREAU OF THE CENSUS


ORANGES* - TREES OF ALL AGES
NUMBER, 1954
35%
60%
4%
UNITED STATES TOTAL
45,830,524
*INCLUDING TANGERINES AND MANDARINS
1 DOT = 50,000 TREES
(COUNTY UNIT BASIS)
US DEPARTMENT OF COMMERCE
MAP NO A54-192
BUREAU OF THE CENSUS


LEMONS - TREES OF ALL AGES
NUMBER, 1954
95%
UNITED STATES TOTAL
6,531,749
1 DOT = 10,000 TREES
(COUNTY UNIT BASIS)
US DEPARTMENT OF COMMERCE
MAP NO A54-194
BUREAU OF THE CENSUS

References, Chapter II

1. H. C. Sherman and C. S. Lanford, Essentials of Nutrition, 4th ed., New York: Macmillan (1957), p. 103.

2. A. A. Albanese, Journal of Clinical Nutrition, Vol. 1, no. 1, (1952), p. 51

3. L. E. Holt and A. A. Albanese, Transactions of the American Association of Physicians, LVIII, (1943), p. 143.

4. A. Davis, Let's Eat Right to Keep Fit, New York: Harcourt, Brace & World, Inc., (1954), p. 68.

5. Adapted from Sherman & Lanford, op. cit., p. 120.

6. K. Moll, J. Cline & P. Marr, Postattack Farm Problems, Part I, report prepared for OCD by SRI (1960).

7. J. J. Wooten & J. R. Anderson, U.S.D.A. Yearbook of Agriculture, 1958, Land, Washington, D. C., p. 53.

8. U.S.D.A. Agricultural Statistics, 1961, Washington, D. C. (1962).

9. New York Times, June 3, 1962.

10. W. Brown, Ed., Strategic and Tactical Aspects of Civil Defense with Special Emphasis on Crisis Situation, prepared for OCD by Hudson Institute, Harmon-on-Hudson, New York, (1963), Chapter V.

11. Adapted from the UN Demographic Yearbook, (1959) as cited in C. P. Wilsie, Crop Adaptation and Distribution, San Francisco: W.H. Freeman, (1962), p. 10.

12. Wilsie, op. cit. See also R. L. Mighell, U.S.D.A. Yearbook, 1958, op. cit., p. 109.

13. E. P. Odum, Fundamentals of Ecology, 2nd ed., Philadelphia: W. B. Saunders Company, (1959), p. 73.

14. The Physician's Desk Reference, Medical Economics, Inc., (1962).

15. D. H. Calloway, J. Bosley and O. E. Reynolds, American Scientist 50: 362A (1962).

16. J. Meyers, J. Aviation Med. 25: 407 (1954).

17. J. G. Gaume, J. Astronautics, IV: 72 (1957).

18. Christian Science Monitor, December 20, 1962.

Additional Reference Not Cited in the Text

Documenta Geigy; Scientific Tables, 6th ed., K. Diem, Ed., Ardsley, New York: Geigy Pharmaceuticals, Division of Geigy Chemical Corporation, (1962). Extremely complete tables showing compositions of food are given on pages 501-513. A bibliography for these tables is found on p. 500.

CHAPTER III

DISEASES AND PESTS IN THE HUMAN ECOSYSTEM

Section §1 covers diseases of humans and of the principal domestic animals. These are treated together because many of the pathogenic organisms are common to both groups. Consequences of a nuclear attack are examined in regard to breakdown of public health standards, shortage of drugs, lowering of resistance and mechanisms of disease propagation. Diseases are tabulated in Annex B.

Section §2 discusses plant diseases from the same point of view. Differences of methods of treatment (control, not cure) are stressed, but the basic considerations are similar.

Section §3 surveys insects (as pests, controls, pollinators and disease vectors) with special consideration to probable radiation dosage of species with different habits. Data on insects (in their various roles) and insecticides is tabulated in Annex C.

Section §4 surveys vertebrates (as pests, disease vectors and insect predators). The importance of season and habits in determining probable radiation dose is emphasized. A short discussion of birds is included.

Section §5 completes the Chapter with a brief discussion of weeds as pests.

§1. Diseases of Animals and Man

Diseases of man (and of animals) are caused by five types of organisms: bacterial (including rickettsial), protozoal, viral, fungal and parasitic worms. The latter are not micro-organisms, and their effects are debilitating but seldom acute.* They are long-lived and generally do not complete their life-cycles in a single host. Hence they do not multiply to any great extent in the human body and propagation can be controlled easily by "cultural" methods, e.g. inspection of food, sanitation, proper disposal of garbage. Diseases due to worms are very unlikely to become a serious menace as a direct consequence of thermonuclear attack.

Fungi are not a serious cause of diseases of animals or man. Less than 50 of the thousands of known species are capable of invading animals or man, and less than a dozen can cause fatal infections. The most common of these is Actinomyces bovis (nevertheless very rare).[1] Only one group, the dermatophytes (which cause skin diseases such as ring-worm) can be spread from animal to man or man to man. These infections, while persistent and hard to get rid of, are not usually serious. Under hot, humid shelter conditions fungus diseases of the skin could spread rapidly and become a serious annoyance.

The remaining diseases, bacterial, protozoal and viral, may have epidemic possibilities which could be influenced by conditions following a nuclear attack. To the extent that these diseases are, or may be, acute they must be considered carefully. Micro-organism populations will not, in general, be affected directly by levels of radiation which would leave any survivors among higher plants and animals.+ Moreover any fluctuations arising from differential radio-sensitivities would be so rapid, due to the very short reproductive cycle of the organisms, that the effects would be averaged out in the time scale of macroscopic ecological events.

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*With some notable exceptions, e.g. trichinosis

+Critical doses are of the order of 10^6 rads.

The critical factors will be lowered disease resistance on the part of animals and man, and mechanisms of propagation. Resistance to disease is a function of general health and the availability of specific antidotes, either internally or externally supplied. Propagation depends on the existence of foci of infection (sick individuals) and carriers.

(i) General health will be affected directly by contact with radiation, both from external sources and ingested via the food and water. Radiation sickness weakens the disease-fighting capability of the body by destroying the cells which manufacture white blood corpuscles. Other injuries (e.g. burns) also cut resistance to ancillary infection. Inadequate diet has similar consequences (especially if vitamin C is in short supply).

(ii) Medicines, anti-biotics, anti-toxins, vaccines etc. supplement or increase the natural resistance of the body. Some or all of these might themselves be unavailable after an attack, due to destruction of stored supplies, manufacturing capacity (and natural sources), and distribution capability,--in conjunction with sharply rising requirements.

(iii) Foci of infection of many serious diseases exist at present in North America, but generally they are quite rare. This fortunate fact argues that epidemics would take some time to get established in a post-attack environment--during which period precautionary measures could be taken and society could get "on its feet" again. However there are two nasty caveats:

a) Hospitals themselves would be overloaded with the worst cases of radiation sickness, burns, etc. Hospitals also are endemic sources of infection (especially *Staphylococci*) due to the constant presence

of sick patients. Food supplies, bed linen, tableware, sanitation gear, etc. are difficult to keep sterile even in normal times. In a postattack environment many diseases could spread like wildfire through hospitals, eventually infecting outsiders (released patients, employees, visitors) and the general population.

b) Biological warfare might be combined with a nuclear attack.

(iv) Carriers are involved in the spread of most serious diseases. Transmission may be direct from sick to healthy individuals, but very often an intermediary is involved. These carriers are usually insects, sometimes with other intermediaries as well (e.g. rats).

Principal infectious diseases of man are tabulated in Tables III-1 through III-4 found in Annex B which logically follows at this point. General sources of information on human and animal diseases are listed as references 1-5.

Diseases likely to be of particular concern in hospitals crowded with people suffering from radiation sickness appear to be diphtheria, pneumonia, scarlet fever, and infectious hepatitis.

In crowded conditions outside hospitals typhoid could be a very serious threat. There are still about 2,000 typhoid carriers in New York State, for example. If public health measures should break down, an epidemic could occur very quickly. A recent outbreak in Zermatt, Switzerland illustrates this possibility. Over 300 cases developed, apparently as a result of seepage of sewage into drinking water conduits.

Typhoid can only be treated with very sophisticated anti-biotics (tetracyclines, erythromycin) which might be unavailable (see Chapter II, Section §1). Bacillic dysentery could also become a problem. It responds to similar treatments, but sulfa drugs are preferred.

Murine typhus, a Rickettsial disease, is endemic in rodent populations in the U.S. and is transmitted by fleas. The historic scourge, however, is louse-borne typhus. Drugs do not help much against the Rickettsiae. The best control yet developed is de-lousing by means of DDT powder (if available) and vaccination. Strains of lice resistant to DDT appeared during the Korean war, but U.S. troops were protected somewhat by vaccination. In an epidemic among unvaccinated British troops there was a 32% mortality rate.* Rocky Mountain spotted fever, spread by ticks, is a very similar disease which is widespread in the western U.S.

Tularemia (rabbit fever) and plague are closely related. Both spread from animals, particularly rodents, via insects or direct contact. "Sylvatic" plague is a form endemic among wild animals in the rural U.S., especially in the southwest, but it rarely spreads to humans. The epidemic version of plague (bubonic or pneumonic) is spread by rats and

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*Zinsser[7] makes an excellent case for his contention that typhus has affected the outcome of a number of critical battles in history, e.g. Napoleon's disastrous retreat from Moscow in 1812, and the Austrian invasion of Serbia in 1914. In crowded conditions (military operations, refugee camps, evacuations, etc.) measures to control lice may break down, opening the door to typhus. In World War II, 10% DDT powder was effective against lice, but since resistance has developed new techniques would be needed.

fleas.* The most effective treatment is a combination of streptomycin and aureomycin (one of the tetracyclines); and some sulfa drugs are helpful for the bubonic form only.

Cholera is spread by contaminated food and water, via the oral route. The disease is much less serious if patients can be kept from dehydrating; hence the mortality in epidemics where nursing is scanty. Sulfa drugs help somewhat, but anti-biotics seem to be ineffective.

Smallpox, a virus disease, does not yield to anti-biotics, though re-hydration and therapeutic measures may help. Vaccination, the standard method of control, often wears off after a few years and much of the population would be relatively unprotected if an epidemic should occur.+ Mortality among unvaccinated children is extremely high--about 80%.

Malaria is carried by mosquitoes of the genus <u>Anopheles</u>, several species of which occur in the U.S. including one species known to be implicated. The disease was formerly endemic but has been pushed south by swamp drainage, public health, and other control measures. It could return if, for example, insecticides became scarce and conditions chaotic. Yellow fever is also thought of as a tropical disease, but its principal carrier, the yellow fever mosquito, is common in the southern states.

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*The most effective preventive measure against epidemic plague is rodent control. A new rat-poison, warfarin, is a great improvement over earlier poisons, being very slow-acting (hence relatively safe for use in human habitations). It is an "anti-coagulant" which nullifies vitamin K and causes the rat to die of internal hemorrhages. This poison is only useful against a small, stable rat population, e.g. in a shelter or granary, but there it is very effective. Supplies might be limited in a postwar environment until manufacturing capacity for sophisticated chemicals returned.

+<u>Zinsser Microbiology</u>[1] estimates the figure at 75%.

The same mosquito carries dengue (breakbone) fever, certain types of encephalitis, and the roundworms which cause elephantiasis. Any of these could flare up given a focus of infection and a relaxation of controls. Malaria symptoms can be alleviated (if not cured) by quinine and several related compounds. The only control for yellow fever is vaccination. Once the disease has been contracted little can be done (mortality can be very high: up to 80% in severe epidemics, though usually in the 40% range).

The worst carriers of human disease are certainly mosquitoes, followed by flies, lice, ticks, and fleas. Other arthropods (e.g. cockroaches, mites, chiggers, bedbugs, etc.) may occasionally act as infective agents but are seldom important. As alternate disease hosts, rats are frequently definitely implicated, and livestock, dogs and birds occasionally.

Animal Diseases[4]

There are only four domestic animals of substantial importance in the human ecosystem in the United States, namely cattle, swine, sheep, and poultry. All are sources of food or fiber. Horses and mules have been almost completely replaced by motorized vehicles. Cats and dogs usually function only as pets,* seldom being used as protection, for catching rodents, etc.

Wild animals interact with man in a more indirect way. Fresh water fish are a minor source of food. Ocean fauna are more important, especially

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*Seeing-eye dogs are a special problem, but would accompany their owners and rarely pose serious veterinary or dietary problems. Dogs also have some importance in sheep and cattle ranching in the U.S.

in certain coastal regions, but the ecological relationships involved are extremely complex (and probably several orders of magnitude less critical) than dry-land problems arising as a result of nuclear attack. Hence we shall not discuss them. Wild birds and small insectivorous vertebrates are an important factor in dry-land ecology. Wild herbivores (deer, rats, rabbits, etc.) are only important insofar as they are competitors for plant food or reservoirs of disease. By and large diseases of wild animals cover too large a range of possibilities and affect man too indirectly to attempt to analyze them here.

In regard to domestic animals, disease treatment and prevention methods are generally similar to methods used for humans, e.g. clean food and water, insect control, improved diet, etc. There are three major differences:

(i.) Animals can be bred, deliberately, to develop disease resistant strains. This is usually a secondary objective for stock breeders, however.

(ii.) Diseases can be eliminated by destruction of sick animals. This was done and is being done for a number of diseases, e.g. hoof-and mouth disease, bovine TB, pleuropneumonia (of cattle), dourine and glanders (of horses), hog cholera, rabies, brucellosis, and others.

(iii.) Animals are unable to obtain medical aid at the first onset of the disease, but must wait until symptoms are obvious to an observer.

Points (i.) and (ii.) operate in favor of effective disease control. Point (iii.) operates against it, but this can be mitigated by alert, trained veterinarians and farmers, and regular health inspections. Diseases may be transmitted through a whole herd (in a bad outbreak),

as a result of direct contacts between animals, but transmission from herd to herd or farm to farm is inhibited by the relative isolation of the various groups of animals from one another. This factor does not help as much against diseases borne by mobile insects, however.

A thermonuclear attack would influence the spread of diseases among animals by causing a lowering of disease-resistance, by inhibiting treatment and control, and by affecting mechanisms of propagation. As with humans, general health of animals will be affected by radiation, both external and ingested. Since all the domestic animals are herbivorous, there may be a serious problem of supplying uncontaminated or decontaminated feed. To the extent that stored grain supplies are required for direct human consumption, they would be unavailable for animals. If the attack is severe enough so that food is a limiting factor, animals become competitors for the basic supply of plant foods. The rational procedure in such circumstances would be to slaughter weakened or diseased animals, saving the limited supplies of feed, medicines, etc. for the remainder which would be used as breeding stock when conditions permit. Farmers and ranchers would probably be reluctant to carry out this drastic program, even if they had the necessary facilities, unless preattack and postattack educational programs were instituted.

Supplies of medicines, anti-toxins, vaccines, etc. would be limited. However, since domestic animals will tend to receive radiation doses roughly in accordance with the prevailing outside level, any major attack would probably reduce the livestock population approximately in proportion

to the over-all severity of the attack and the resulting damage to industry and transportation. If general food shortages and sporadic outbreaks of animal disease led to further slaughtering and reduction of herds, the available supplies of biologicals might be adequate for the needs of the remaining animals.

Disposal of carcasses slaughtered or killed animals could be a serious problem. To the extent that it was impossible or inadvisable (due to residual radio-activity) to bury or burn all of them, breeding grounds for many disease organisms and insects (particularly flies) would be available. Very large populations of some species would be built up. The consequences seem more likely to be in the nature of a general health hazard, however, rather than a danger of breeding specific epidemic diseases, since the organisms causing disease in live animals generally perish with the host. This should be studied in more detail, however. For example, the spore-forming bacteria _Bacillus anthracis_ producing anthrax (one of the most widespread and dangerous diseases both of animals and man) retain their viability for many years in soil, water, or elsewhere, even under extreme conditions of temperature and humidity, although they do not multiply rapidly except in the blood stream of a warm-blooded animal.

2. Diseases of Plants[8]

Diseases of plants are generally caused by bacteria, viruses, fungi, and helminthes or nematodes. Because of complicated life histories, slow breeding rates, and lack of mobility, helminthes (worms) do not seem likely to become a more serious menace than at present as a result of the effects of a nuclear attack. Hence we shall concentrate on the other types of disease.

The factors which determine vulnerability of hosts and rate of spread of plant diseases are:

(i) the inherent resistance of the plant

(ii) the nature of the pathogenic organism

(iii) the environmental conditions

Items (i) and (ii) could be important if mutations induced by widespread radioactivity increase the rate at which virulent strains of pathogens evolve. The extent to which this "mutation" factor is important depends on how much reliance is placed on cross-breeding to obtain immunity to disease. In the case of plants, particularly cereal grains, the development of hybrid varieties of plants is in a neck-and-neck race with the natural evolution of dangerous new strains of pathogens. Thermonuclear war could conceivably upset this equilibrium by increasing the rate of mutation, while inhibiting the production of new hybrid species. However, the evidence in favor of the above is merely presumptive at present, since the exact role of mutations in evolution has not been established.

The foregoing considerations would appear to apply (if at all) to plant diseases much more than animal or human diseases, in proportion to the relative importance of eugenics. Humans do not practice eugenics to

any extent at all, and stock-breeders breed mainly for qualities such as milk or egg productivity, rather than for disease immunity. Vaccinations and innoculations serve a useful function for farm animals and humans, but would be uneconomic to use on plants (except orchard trees). Differences in methods of control and treatment between plants and animals are a function of the difference in value of the individual units.

The environmental conditions, item (iii) above, are the most subject to change as a result of thermonuclear attack. These changes may be of several kinds:

First, an attack is likely to influence methods of cultivation, availability of fertilizers, fuel, pesticides, etc:

Second, an attack may cause changes in the weather, which in turn influences vulnerability to infection both directly and indirectly. The indirect effects touch on the actions of disease propagators (insects, wind, etc.) mentioned below.

Third, an attack may alter the mechanisms which spread the disease.

The first point covers a multitude of possible complications. We can hardly do more than indicate a few of the possibilities.

Fertilizers.[9] Plants, like animals, are subject to deficiency diseases. For example, lack of boron inhibits growth of roots and tops. Shortage of calcium causes breakdown of meristematic tissue (growing points). Copper deficiency causes dieback (exanthema) of citrus trees and other fruit trees, malformations of seed heads and withering of young leaves on cereal grain plants, and poor growth of lettuce and onions. Chlorosis (yellowing) due to iron shortages occurs in deciduous trees and

pineapples; lack of magnesium can produce this effect on tobacco, corn, citrus and apple trees. Manganese deficiency causes chlorosis and necrosis of tomatoes, oats, snap-beans, tobacco, etc. Molybdenum shortage causes whiptail disease of cauliflowers, and various diseases of tobacco, tomatoes, and legumes. Too little or too much nitrogen leads to numerous symptoms in a variety of plants.

Several diseases caused by pathogenic organisms occur primarily where mineral deficiencies (or excesses) exist in the soil. Among them are wheat root-rot, take-all disease of wheat, powdery mildew and rusts of cereals, Texas root-rot and fusarium wilt of cotton, club-root of cabbage, common scab of potatoes and seedling diseases of sugar beets. To the extent that fertilizers are unavailable as a result of nuclear attack, many of the foregoing can be expected as a consequence.

Fuel. There is reason to believe that gasoline for running farm machinery is not likely to be one of the most critical factors in a post-attack situation* due to wide distribution of oil wells throughout most farming regions, and the relative simplicity of producing low grade tractor fuel.[10] However, if shortages do occur (e.g. in Iowa, where there are no oil wells) such operations as deep plowing of legumes, mechanical weed-control, rapid harvesting, etc. would be curtailed, inhibiting cultural methods of disease control such as plowing under stubble.

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*This point is definitely controversial. Also, there is the possibility of a deliberate or semi-deliberate attack on oil fields and refineries, which would alter the situation drastically.

<u>Pesticides</u>. Fungicides and herbicides are used directly in disease control. The former are used at times on almost every kind of crop. The latter (mainly 2-4D) are used primarily to destroy weeds (e.g. in hedgerows, ditches, etc.) which act as breeding grounds for disease carrying insects or as alternate hosts for some fungi. One example is the black stem rust fungus <u>Puccinia graminis</u> which (in the north) must over-winter on the leaves of the barberry plant.

The second possible influence of thermonuclear attack, e.g. on the weather, will be discussed at more length in the next Chapter (IV). Here we shall simply indicate some of the numerous interactions between climate and plant diseases. Many bacterial plant diseases thrive in warm weather, while fungal diseases typically prefer cool damp weather. However, the resistance of the plant-hosts is also temperature dependent. Crops grow best where the climate is optimal for them and least encouraging to their pathogens. Thus corn is most resistant to blight at soil temperatures above 75° F, while wheat has maximum resistance at 54° F. A change in the meso-climate, e.g. a shift of several hundred miles north or south in the (seasonal-average) soil-temperature, isotherms, could result in drastic increases in vulnerability of many crops to diseases. It should be noted that in the midwestern U.S. a change of 1° C. in average temperature would cause the boundaries of regions climactically suitable for a given crop to shift approximately 100 miles north or south. A drop of 6-7° C. (see Chapter IV) would be a very serious matter.

The pandemic of potato late blight (a fungal disease) in Ireland in 1845 and 1846--the cause of the disastrous famine and depopulation--resulted from unusual weather conditions. This disease spreads with

explosive speed when circumstances combine to produce a long period of rainy or foggy cool weather early in the growing season. The appearance of this combination two years in succession is especially dangerous since there are mar overwintering spores of the fungi at the beginning of the second season.

A severe outbreak of wheat stem rust is also likely to follow extended damp cool spells in the southern wheat growing regions, moving gradually north as the spores are spread by the wind, followed by hot dry weather at the time when wheat kernels are forming on the blighted plants. This occurred in 1935 and resulted in the loss of 25% of the United States wheat crop, and 60% of the crop in North Dakota and Minnesota.[11] This bears on the third potential influence of a nuclear attack, namely mechanisms of disease propagation.

Climate affects the spread of disease also insofar as it determines the number of overwintering carriers (mainly insects). Normally harsh cold during the winter will kill many of the temporary hosts. Interactions with insects are discussed separately in the next section (§3).

One consideration worth mentioning in connection with disease spread has been suggested by Stonier.[12] A large number of diseases and pests move from south to north as the growing season progresses. The stem rusts of wheat, mentioned above, are one example in which wind is the primary carrier. Other diseases are carried by insects which winter in the south and gradually move north as the year advances. Fallout patterns following a nuclear attack would tend to run east-west, especially across the Mississippi Valley and the great plains. The northern progress of

insects and windblown spores would therefore be interrupted at intervals by swathes of fallout contaminated land. The consequences would depend on the time of year. Consider two cases:

A. An attack before the crops had been planted would dump fallout over fallow or ploughed fields. Farmers in contaminated areas would probably not attempt to plant. Hence the fields would produce mostly weeds, and grass from stray windblown seeds (or nothing at all, if the fallout were heavy) and would act as "attenuators" of the northbound disease vectors.

B. An attack after planting would find partly grown crops, which would be weakened by radiation from fallout. Lack of attention by farmers would subsequently result in further loss of over-all ability to resist infection. The result might well be the reverse of case A, e.g., the radioactive strips of weakened crops might "amplify" the disease vectors, paving the way for a disastrous outbreak.

3. Insects.

Insects* interact with the human environment in several ways, e.g. as parasites on domestic animals or on crops, as predators of other insects, as pollinating agents, and as carriers of disease. These interactions are, for the most part, well known (at least qualitatively). We shall therefore forego any descriptive introduction, except regarding the role of insects as disease spreaders.

Table III-5 shows the percentage of production losses of crops due to depredation of insects, and diseases. For the most part insects are the agency by which these diseases are spread.

Annex C, which might logically follow Table III-5, contains extensive tabulations of the principal pests of crops (Table III-6), livestock (Table III-7), and forests (Table III-8), with data on habitats and controls. Table III-9 lists beneficial insects (predatory, parasitic, and pollinating), with cross-references indicating prey, crops benefitted, etc. Tables III-10, III-11, and III-12 show insects as disease carriers of viral, bacterial, and fungal plant diseases respectively. Insects as carriers of human and animal diseases have been covered in Tables III-1 through III-4 of Annex B. Further cross-referencing is provided by Table III-13, which lists the principal insecticides, fungicides and herbicides, together with the pests against which they are normally used.

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*We include some other small animals such as spiders, mites and ticks with the insects.

TABLE III-5

Production Losses of Crops (1942-51)[13]

	Insects (as pests)	Disease	Total
cotton	15% (bollweevil 10.1%)	17.5%	32.5%
dry beans		11.5%	
corn	3.3% (earworm 1.2%) (E. borer 1.9%) (SW " 0.2%)	4.8%	8.1%
oats	0.6% (greenbug)	21.3%	22.9%
rice		5.9%	
wheat	2.0% (stem sawfly 0.2%) (Hessian fly 0.9%) (Greenbug 0.9%)	6.6%	8.6%
soybeans	(chinch bug)	8.3%	8.3%
peanuts		19. %	
sugar beets		16.9%	
soybeans		12.5%	
alfalfa (hay)	9.3% (pea aphid & spittlebug)	36 % (27% bacteria) (6% viruses) (3% nematodes)	45.3%
alfalfa (seed)	35. % (lygus)	9% (6% virus) (3% nematodes)	44. %
citrus fruits	14. % Florida 5. % California	3. %	17. % Florida 8. % California
grapes		4. %	
apples	14. % (codling moth 11% (maggot 3%	6. %	20. %
snap beans	9. % (Mex. bean beetle)	22. %	31. %
cabbage		8. %	
lettuce		12. %	
potatoes	15.6%	20.1%	35.7%
peas	2.4% (weevil)	23. %	25.4%

Some comments on the synergistic interaction between insects and pathogens will serve to illuminate the probable effects of a nuclear attack.[14] It has already been mentioned that spores of some plant diseases are spread by the wind. A few depend on birds or other agents. The majority move from plant to plant via insects. However, the details of the interrelationships are complex.

The simplest case is where the insects merely serve a mechanical function, as a vehicle. The insect picks up spores or pollen (on its feet or body) from a sick plant and deposits them on a healthy one, more or less at random. Honeybees and other nectar-collectors are often involved this way (e.g. in spreading fire blight of apples and pears).

Sometimes the insect is specifically attracted to the diseased plant by an attractive smell, but otherwise the interaction is mechanical. Thus flies are attracted by a sugary substance produced by ergot (fungal) disease of rye. In some instances wind-blown spores must find openings, such as insect bites, to grow on the new host.

More often insects are required simultaneously for both functions, transportation and penetration of the outer skin of the plant. Many fungal diseases of trees gain entrance with bark beetles, for example, the Dutch elm disease and the blue stain disease of pine trees.

A still more intimate relationship exists in some instances where the insect serves as an alternate host (e.g. for overwintering: bacteria *Bacterium stewartii*, causing wilt of sweet corn, winter in the bodies of the corn flea beetle). The relation may be parasitic or even symbiotic

if, for example, the bacteria supply vitamins or enzymes for the insect host.

Some fungal diseases involve sexual mating between spores of opposite sexes. One case is the black stem rust of wheat, _Puccinia graminis_, which winters on barberry leaves where a sexual mating must take place. This is normally accomplished with the help of insects feeding on the leaves.

In the preceeding text and the two Annexes, B and C, we have indicated a number of ways in which insects are important factors in the human ecosystem. We now turn to the question of how a thermonuclear attack on the U.S. might affect insects in these various roles. This question largely reduces to a corollary: how would insect populations be likely to change?

Initially it can be taken for granted that populations of insects as well as other animals will be reduced. Many insects will be killed by fires. Others will die of radiation poisoning, particularly fertilized eggs (with low sensitivity) which are exposed to fallout. A gamma radiation level of 1000 roentgens/hr. would probably kill most eggs in this stage of development (see table I-3, Chapter I,§3). There is some slight evidence that insects may be several times more sensitive to neutrons than γ radiation as are higher animals (table I-4). Also, insects are apparently at least as sensitive to β radiation. To the extent that they come directly in contact with fallout, β radiation would be much more important for insects than γ radiation (the reverse of the situation for large animals, due to the fact that the surface β dose is typically as much as

forty times as great as the γ dose). Insects with hairy bodies such as bees, moths, butterflies, etc., may also be inclined to pick up some fall-out particles, as they do pollen, and carry them around externally.

Insects will also ingest fallout in their food, but the amount will depend on their habits. Leaf chewers such as grasshoppers, crickets, caterpillars, bean beetles, adult Japanese beetles, etc., are likely to be most subject to this hazard. Juice-sucking insects such as aphids, leaf-hoppers, and white flies will ingest less, due to discrimination factors in the plant. Burrowing insects such as bark-beetles, weevils, maggots, worms, etc., are safest, from both external and internal doses. Predatory insects such as praying mantids, lady-beetles, etc., will receive external doses comparable to those of their prey and will ingest amounts proportional to the quantities retained in the tissues of the prey. Insects spending their larval period underground will get much smaller doses during the most sensitive stage of the life-cycle. In terms of dosage received we would expect the order to be roughly as in Table III-15, with the largest over-all doses at the top. Dosage received at an early stage in the life-cycle is weighted most heavily to take into account the correspondingly higher sensitivity at that period.

TABLE III-15

PROBABLE DOSAGE SCALE (INSECTS)

1.	caterpillars, (moths, flies, bees, etc.*)	leaf-chewing larval stage.
2.	aphids, leaf-hoppers, scales, spider mites	leaf-sucking larval stage.
1.	lady beetles, praying mantids, lace-wings, spiders	predators of above
2.	parasitic wasps and flies	parasites of above
3.	mosquitos, mayflies, caddis fly	aquatic larval stage
4.	bollworms, borers, maggots, etc.	eggs hatch on surface, larvae later bore into fruit or plant
5.	Japanese beetles, grasshoppers bark beetles, wireworms, sweet potato weevils, white grubs (may beetle), etc.	eggs and larvae buried in earth or plant; adults emerge.

* Larvae fed on plant material such as pollen and nectar which would probably be contaminated with fallout

The difference in accumulated dosage during the larval stage is probably of the order of 100-1 from top to bottom of the table. Differences in sensitivity in the egg-larval stage from one species to the other are probably less than this. Since gamma radiation of 1000 r/hr. corresponds to β radiation of the order of 40,000 r/hr., insects exposed to the full dose would by no means be immune and a protection factor of 100 is highly significant. Thus differential radiosensitivities and differential dosages will be critical.

One question which is important is whether the differentials are likely to favor predators or prey (e.g. as between insects and their enemies

or their food supply). One factor which bears on this is the cycling of nuclides in the food chain from prey to predators (see Chapter I, § 4). If the cycling results in concentration of some nuclides at a rate faster than its radioactive decay, the cycling would favor the prey. By the same token, if the concentration were slow, the predators would be favored. During the early time of very rapid decay the predators would normally receive smaller doses than the prey, even if biological concentration were important, but at later times the situation might be reversed. Where the isotopes are discriminated against (e.g. de-concentrated) the predators would always receive a smaller dose. The actual effects, of course, depend on the radiosensitivities of the species.

Differential perturbations on an ecosystem can have complex ramifications. Populations are determined by a balance between several pressures, one of which is "environmental hostility," including climate as well as radiation. Climatic changes certainly influence insect survival. Many insects, in particular, are killed by cold weather or hot dry weather or wet weather. As a general rule, the wilder the oscillations, the fewer insects survive. To the extent that weather were influenced by a thermonuclear attack (Chapter IV), insect populations would be affected.

Availability of food supply is another factor. Differential radiosensitivity is one of the determinants, of course. Thus, if plants are more sensitive than insects, they will soon be overwhelmed. Experiments have shown that defoliation rate in an irradiated forest rises to 10 or more times the normal rate, presumably because the trees are weakened and

and produce fewer leaves, whereas the number of insects is unchanged.[15] We shall return to this point in Chapter IV in regard to forests and watersheds.

The agricultural activities of man are probably the strongest influence on food supply for insects. Whether fields are planted in grains or grow up in weeds determines which insects will thrive in the area. Whether insecticides and herbicides are applied, or not, is equally important. Grazing and irrigation, also play a part. One of the worst potential pests, the grasshopper, (which is near the bottom of Table III-15) thrives in arid marginal grasslands which tend to be overgrazed easily*. Grasshoppers, themselves, once established, can overgraze the land quite efficiently. Loss of irrigation water, in many dry areas in the west,+ could result in grasshopper invasions--to name only one possibility. Another example of how thermonuclear attack might result in sudden changes in the food situation was described at the end of section §2, in connection with the spread of plant diseases. Of course the interaction between insects and disease can also operate in the other direction, e.g. diseases might wipe out certain crops, resulting in starvation for the insects which depend on them for food, or in otherways.

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*Probably they prefer the local "micro-climate" e.g., patches of bare hot earth to lay eggs in, plus patches of vegetation to feed on.

+See Chapter IV, Section §2 and Annex D. Loss of power for pumping, silting or flooding would be the most likely cause of difficulty, rather than water shortage *per se*.

§4. Higher Vertebrates

Higher vertebrates interact with man in a number of ways, as do insects. Two particular interactions are of especial interest:

(i) Higher vertebrates as insectivores

(ii) Higher vertebrates as competitors with man for a limited food supply.

The discussion will be kept rather brief, as a consequence of two salient facts: first, vertebrates are extremely sensitive to radiation and second, they reproduce slowly (compared to insects). Therefore, on the face of it, if radiation is widespread vertebrate populations will drop more and recover much more slowly than insect populations.

There are, however, one or two caveats which should be appended to the above. First, as was pointed out in section §3, some insects at least will receive a much higher dose (because of close contact with β emitting fallout debris)* which partially compensates for their higher average radiation resistance and reproductive rate. Second, many vertebrates will receive a considerable degree of protection, especially if the attack should take place during the winter.

Bears, woodchucks, racoons, skunks, bats and marmots hibernate underground or in caves during the months from October through March. This torpid or comatose state reduces their radiosensitivity along with metabolic rate. Others, such as squirrels live on stored food and do not forage. Cold-blooded

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*Small vertebrates will also receive a higher proportionate dose than large ones. Possibly more important, contact with β emitters could have debilitating specialized effects--e.g. bad burns on the feet or snout, loss of hair, etc. It has been pointed out[16] that birds might lose feathers, as a result of β burns, condemning them to starvation on account of inability to fly.

insectivorous vertebrates such as snakes, toads, frogs and turtles also find crannies or crevasses to hide in and go into a state of virtual hibernation. Moles and water-voles do not hibernate but live in tunnels underground which they seldom if ever leave at any time. Rats and shrews either burrow or find man-made shelter (barns, haystacks, woodpiles, granaries, etc.) during cold weather; shrews hunt mice as a change from their summer diet of insects.*

Many of the insect-eating birds migrate during winter, but relatively few species leave the continental U.S.; many winter along the Gulf Coast. The woodpeckers and flickers are permanent residents as far north as Washington, D.C. and San Francisco, but they normally live in holes or excavations in trees and would have at least part-time protection.

Only deer, rabbits, and field mice, among the normal summer herbivorous or insectivorous population remain in the open during winter, along with the carnivores: coyotes, foxes, lynx, bobcats, weasels, etc. However, the smaller animals also spend much of their time in caves or burrows.[17]

During approximately half of the year much of the insectivorous and herbivorous vertebrate population would receive a considerable degree of protection. In a cave or deep burrow the protection factor would be quite high, of the order of 1000.+ Even in a shallow hole or crevasse in the rocks, or under several feet of snow a protection factor of 20 or so is not unlikely. The protection factor varies widely from species to species, of course. As in the case of insects, Table III-16 lists them roughly in order, starting with the animals likely to receive the highest radiation dosage as a result of a winter attack:

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*Shrews are incredibly efficient at killing insects. A shrew consumes 8 times his body-weight each day and will starve in a few hours without food.

+For a burrow three feet deep, which is average except for mice.

TABLE III-16

PROBABLE DOSAGE SCALE (ANIMALS)

1.	Deer, moose, elk, lynx, bobcat,	no shelter
2.	rabbit, hare, fox, coyote, field mouse, weasel,	part-time in shelter
3.	rat, shrew, woodpecker	active, but sheltered
4.	squirrel, vole,	inactive, but sheltered
5.	hibernating species; mole	
6.	migrating birds	elsewhere.

After a heavy attack most of the population in categories (1) and (2) would probably die. Many in categories (3) and (4) might die also. The hibernating species; moles and migrating birds would be virtually unharmed during the most dangerous period. As a result of the death of many of the large herbivores and top carnivores there would (other things being equal*) be a surplus of forage and few enemies for the smaller herbivores, which incidently are capable of very rapid reproduction. One result of an attack in November or December, with widespread fallout over wild lands, would probably be a tremendous outbreak of rodents (possibly in the second year). In this case, at least, the principal vertebrate insectivores would not be seriously depleted; at least, not to an extent which could not quickly be made up by natural reproductive capacity. For example. brown rats, *Rattus norvegicus*, under ideal (laboratory) conditions, are capable of multiplying by a factor of 221 in one year.[18]

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*Which, of course, they are not--but the point is clear.

We note, therefore, that the loss of all vertebrate insectivores (especially birds and shrews) would be a serious blow. But, for a part of each year, over a large segment of the country, the birds, shrews, etc. are likely to survive an attack in numbers large enough to be quite effective against insects, whereas the rats would have little competition. In summer, or in the southerly areas during the winter, on the other hand, the shoe would probably be on the other foot and insects would be the principal survivors.

The potentialities of rodents (in particular) for population explosion are easily substantiated. In one typical area, northwest Texas, population explosions of cotton rats and bobwhites (quail) have occurred simultaneously twice in the last 25 years: 1942 and 1958.[19] In each case, the explosion came because of a sudden increase in food supply as a result of a sequence of events following recovery from a drought. When the favorable food situation ceases as a result of changes in the plant succession rats, being better competitors, tend to drive the quail into less favorable range (where many starve) and devastate the country.* Rat predators (hawks, owls, lynx, etc.) may or may not affect the outcome (in 1943 they did, in 1959 they did not).

*In neither instance was sylvatic plague a factor in the eventual extermination of the rats, or was it apparently transmitted to humans.

Birds

A few remarks about birds as the principal vertebrate insectivores, may be worthwhile. Insects comprise 2/3 of the yearly diet of the common land birds in North America.[20] The exact insect species eaten by each individual bird depends on the season and the range. For example, robins are known to eat insect larvae in the early spring and caterpillars, grass-hoppers, bugs, spiders and various beetles during the rest of the year. The other common insect-eating birds show the same lack of preference in their diets with a few exceptions. As a rule, swallows, flycatchers and swifts catch insects in the air; whereas, members of the thrush family (robins, blue-birds and thrushes), and blackbirds consume ground-living insects. Woodpeckers generally pick insects out of the bark of trees. Flickers, although members of the woodpecker family, seem to prefer insects, especially ants, found on the surface of the ground. Chickadees, crows, starlings, jays and others live partly on insects and partly on seeds and fruit. Pigeons, quail, pheasant and grouse are vegetarians. Hence these birds tend to be permanent year-round residents. Except for woodpeckers, most insect-eating birds must migrate, due to inadequate winter food supply in the higher lattitudes.

No definite information exists on the relative importance of birds in controlling insects especially in large outbreaks.[21] It is known, of course, that birds do eat large numbers of insects. Stonier quotes a study of English sparrows in Salt Lake Valley, which suggested that one brood of birds, during the 10 day period before leaving the nests, would consume approximately 20,000 insects (alfalfa weevil larvae or others of equivalent bulk).[22] There is some evidence that birds are attracted to

areas where insects are plentiful, and are reduced in numbers where insects are reduced, e.g. by spraying. For example a 10 year census of breeding birds in a 20 acre lot in Massachusetts (1920-29) showed a substantial reduction (about 45-50%) in nests following 3 years of applications of arsenic sprays to control the gypsy moth.[23] The importance of birds in controlling or preventing large scale insect outbreaks is questionable. There is a tradition that a severe 19th century outbreak of Morman crickets in Utah was brought under control by gulls, though the explanation may lie in a local concentration of gulls rather than large scale population control.[24] The Engelmann spruce beetle epidemic in Colorado continued for ten years, despite the efforts of woodpeckers which locally reduced beetle populations from 45 to 98% compared with control populations.[25] (See Appendix II.)

It is a moot point, in many cases, whether birds do more harm than good, even when they stick largely to insects. Since birds are rather indiscriminate in selecting insect food, they often consume beneficial insect predators, such as dragonflies and lady beetles, proportionately as often as or more often than pests. Predator insects are frequently larger and therefore more tempting than their prey. (On the other hand, parasitic insects tend to be smaller and therefore less tempting to birds.) Unfortunately little is known about these complex population interactions. Fears regarding the ecological consequences of widespread destruction of birds are based on little more than intuition. One predictable result would be the relatively greater importance of large predaceous insects (compared to small parasitic ones) in the ecological scheme of things.

To the extent that birds eat seeds and fruit, it is frequently assumed that they are a nuisance. In cultivated fields, this may be so, but the same birds also eat seeds of undesirable plants (weeds) and the real question is how the balance of the two would be affected if birds were absent.

It would seem that birds would be affected to a great extent even if an attack should occur in the winter. Fallout patterns indicate that an attack in the winter would affect many of the common birds who migrate only as far south as Texas and the Gulf States as well as those who do not migrate to any great extent and those who migrate south from Canada. A summer attack would, of course, be hazardous for all of the land birds not only because of the direct effects but because of the contaminated food supply.

§ 5. Plants as Pests (Weeds)

'Weeds' are plants of no positive value, or even a negative one. In most cases they are transitory, being followed in the succession by grasses or brush and finally trees, as the case may be. At times certain vigorous species of nuisance plants, or weeds, have shown themselves capable of invading new territory on their own. For example, the prickly pear cactus introduced into Australia accidently, spread over (and ruined) 60 million acres of grazing land by 1930. Similarly Klamath-weed or goatweed, imported from Europe (where it was called St. Johns wort) invaded 2.5 million acres of rangeland in the U.S. by 1950. In each case the weed was controlled by importing an insect from the weed's native habitat.*

There is no universal set of characteristics by which "weeds" can be distinguished from crop plants, except that of being unwanted. Hence one cannot analyze the effect of a thermonuclear war on weeds _per se_ except for a simple minded remark: as a result of lack of cultivation weeds will increase vis-à-vis crop plants. This is not due to any special characteristics of weeds, however, but due to a characteristic of the cultivated agricultural eco-system: namely, the system is not in its natural equilibrium state, but in an artificial one maintained by the farmer's efforts. Without them the eco-system returns to its natural state, in which weeds have at least a transitory role.

It can be argued that weeds have an advantage in a postattack environment: weeds are nature's generalists, crop plants are specialists.[27]

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*An Argentinian moth, _Cactoblastus cactorum_ brought to Australia in 1930, cut the prickly-pear infestation by 95% in 7 years. Two beetles imported from southern France, _Chrysolina gemellata_ and _C. hyperici_ between 1944 and 1948,[26] had reduced the weeds by 99% in 1959 (to a stable residual population).[26]

Generalists are more adaptable than specialists to new situations, ergo weeds take over. To the extent that this is true, it probably means that there exist some weeds which will adapt to (almost) any particular new situation, whereas a given crop plant may not. In other words, "weeds" as a class are more adaptable than any particular species of plant. Still another statement of the same basic truth is that if we change the eco-system in some arbitrary fashion (e.g. by dumping a lot of radio-active debris on it, etc.) those species which will be found to adapt best to the new conditions will, in all probability be (i) different from the species which are at present 'best' adapted and (ii) useless to humans (hence "weeds").

D. S. Grosch[28] has pointed out that weeds may serve one useful purpose in a postattack environment, namely as a disposable cover-crop. A substantial percentage of the soluble radio-nuclides from fallout might be incorporated in a weed crop which could subsequently be scraped off or "harvested" for disposal.

The analysis of attack consequences cannot proceed further without considering various species of weeds, individually. The scope of the present report precludes such detailed discussion here.

ANNEX B

(to Chapter III § 1)

Table III-1 (1)

SERIOUS, CONTAGIOUS

BACTERIAL DISEASES OF MAN

DISEASE	CARRIERS	CAUSE, SOURCE & TRANSMISSION OF INFECTION	SUSCEPTIBILITY, IMMUNITY & INCUBATION	PREVENTION & TREATMENT
Cholera	Healthy people, convalescents carry organism 7 - 14 days after recovery. Flies	*Vibrio comma* found in feces and intestinal contents, food and water. Food and water. Direct or indirect contact with patients or carriers. Attacks intestines	Natural resistance varies. Those with gastrointestinal difficulties particularly susceptible. Attack occurs a few hours to 5 days after exposure.	General sanitation, protection from flies. Pasteurization of milk. Anything touched by patients should be disinfected or destroyed. Treat: some results with cholera bacteriophage* or sulfonamides. Vaccine produces active artificial immunity for 6-12 months. Rehydration.
Meningitis	Chronic carriers carry Group II bacteria to which not many people are susceptible	*Neisseria meningitides* (4 serological groups) Nasopharynx, blood, cerebrospinal fluid of infected persons. Direct contact and droplet infection. Attacks base and cortex of brain and surfaces of spinal cord.	Attack occurs 2-10 days after exposure. Usually affects vigorous and healthy rather than sick individuals.	Isolation of infected persons. Avoid overcrowding. Treat: sulfadiazine (for patients and carriers) Penicillin or one of tetracyclines Serum used in cases where serological group is known
Venereal Syphilis:		*Treponema pallidum*	10 to 90 days	Wasserman blood test before marriage.
Gonorrhoea:		*Neisseria gonorrhoeae*	1 to 14 days	Penicillin
Chancroid:		*Haemophilus ducreyi*	6 to 7 days	Sulfonamides, streptomycin
		Infection almost always transmitted by sexual intercourse although syphilis can be congenital.	Reinfection can occur after one attack.	

* A bacteriophage is a virus which attacks a bacteria.

Table III-1 (2)

SERIOUS, CONTAGIOUS

BACTERIAL DISEASES OF MAN

DISEASE	CARRIERS	CAUSE, SOURCE & TRANSMISSION OF INFECTION	SUSCEPTIBILITY, IMMUNITY & INCUBATION	PREVENTION AND TREATMENT
Plague	rodents, Infected fleas can live through winter and preserve plague until following season	Pasteurella pestis found in buboes, blood, sputum, bone marrow, liver, spleen, lymph nodes of sick trans: rat-to-rat and rat-to man, via rat fleas (not by human fleas, also by droplet infection (pneumonic), most significant flea (Xenopsilla cheopis) in transmission of human plague	temporary immunity after disease	live in rodent-free belt almost impossible to get rid of infected rodents Treat: streptomycin and tetracyclines early in disease, sulfadiazine when antibiotics not available. Active immunization from plague bacterin lasts a few months
3 types:	Bubonic--severe, usually fatal; attacks lymph vessels and glands Pneumonic--lungs and peribronchial lymph spaces Septicemic--blood acute septicemic form usually produces rapid death			
Diphtheria	convalescents for 3-4 weeks some chronic carriers exist	Corynebacterium diphtheriae Nasopharynx discharges trans. person to person by fingers, articles, inhalation of droplets Bacteria in dust of ward floors C. diptheriae affects nose, throat and tonsils, forming a false membrane which may spread to entire respiratory tract Organism produces toxin which injures kidney and muscle of heart	Usually life immunity after an attack Resistance increases with age Shick test to determine susceptibility Attack occurs 2-5 days after exposure	pasteurize milk disinfect rooms and soiled articles and isolate sick Treat: passive immunization early in disease with diptheria antitoxin along with penicillin or erythromycin. Antitoxin neutralizes damaging effect of toxin Vaccine produces active immunization.

Table III-1 (3)

SERIOUS, CONTAGIOUS — BACTERIAL DISEASES OF MAN

DISEASE	CARRIERS	CAUSE, SOURCE & TRANSMISSION OF INFECTION	SUSCEPTIBILITY, IMMUNITY & INCUBATION	PREVENTION & TREATMENT
Dysentery (Bacillary)	housefly convalescents and occasional healthy carriers	(1) *Shigella shigae*--most acute and fatal form; mostly in tropics (2) *Sh. schmitzii*--similar to *Sh. shigae*; rather uncommon (3) *Sh. flexneri*--Most common cause of epidemic dysentery. Chiefly in U.S. (4) *Sh. sonnei*--common, epidemic, mild. Spread by contact with contaminated food and water. Organisms expelled in feces.	Most people susceptible, e.g. visitors in tropics incubation 3-7 days	Treat: chloramphenicol sulfonamides for sick and other members of family. (Sulfa drugs induce vitamin deficiency in intestinal bacteria by replacing necessary PABA.)
Typhoid fever	Convalescents or chronic cases. Cure of chronics almost impossible	*Salmonella typhosa* man is sole host, bacillus discharged in feces and urine, passed by contamination of food, milk or water	Attack confers long-lasting immunity	Pasteurize milk, chlorinate water, immunization by means of vaccine. Treatment with tetracyclines, chloramphenicol, cortisone sometimes used for symptomatic relief. Penicillin and sulfas useless.
paratyphoid fever, types A, B, C.		*S. paratyphi* (A) *S. schottmuelleri* (B) *S. hirschfeldii*) *S. choleraesuis*) (C) *S. choleraesuis kunzendorf*)		

New serotypes of Salmonella which show increasing species specificity are constantly being discovered indicating that this particular bacteria is still in a state of evolution.

Table III-1 (4)

COMMON, CONTAGIOUS

BACTERIAL DISEASES OF MAN

DISEASE	CARRIERS	CAUSE, SOURCE & TRANSMISSION OF INFECTION	SUSCEPTIBILITY, IMMUNITY & INCUBATION	PREVENTION & TREATMENT
Pneumonia		(1) Diplococcus pneumoniae (32 types) Usually produces lobar pneumonia. Organism present in lungs, lymph glands and sometimes blood. Trans: direct contact--inhalation--but can be autogenous infection	Resistance lowered by wet, cold, fatigue, and alcoholism. Short immunity after attack.	Treat: Penicillin tetracyclines, sulfonamides and erythromycin
		(2) Haemolytic streptococcal pneumonia--usually serious Usually a complication of influenza--esp. 1918-19.		Treat: same as above
		(3) Staphylococcal pneumonia Often a complication of influenza or other viral infections of respiratory tract. In hospitals found in patients with leukemia and other malignant disease. Fairly high mortality rate.		Treat: Large amounts of penicillin along with novobiocin, chloramphenicol or erythromycin Vanocomycin (Staph. usually do not develop resistance to this drug)
		(4) Klebsiella pneumoniae (Friedlander's bacillus) Severe or even critical infection High mortality rate Organism often a secondary invader of patient Organism can cause meningitis (mortality about 50%).		Treat: Streptomycin, tetracyclines, chloramphenicol

Table III-1 (5)

COMMON, CONTAGIOUS

BACTERIAL DISEASES IN MAN

DISEASE	CARRIERS	CAUSE, SOURCE & TRANSMISSION OF INFECTION	SUSCEPTIBILITY, IMMUNITY & INCUBATION	PREVENTION & TREATMENT
Scarlet Fever (Scarlatina)	Carriers without active infection or with subclinical infection--most frequent source of infection.	Haemolytic streptococcus (type A) Produces erythrogenic toxin which induces rash. Organism in contaminated milk, pus, sputum and nasal discharges. Contaminated milk can lead to outbreaks Surgery--from infected wounds or burns Direct contact	Dick test for susceptibility Also Blanching test and Rumpel-Leede test White, esp. males, more susceptible than non-white Attack usually 2 to 5 days after exposure.	Isolation of patient for about 2 weeks. Treat: Penicilin or tetracyclines Active immunization: Toxin Antitoxin to neutralize damaging effects of bacterial toxin reduces complications.
	Note:	(Disease may be caused by a combination of streptococci and a virus.)		
Whooping Cough (Pertussis)		Bordetella pertussis Discharges of larynx and lungs trans. by direct contact. Highly communicable	Second attacks are possible although rare. Incubation period of 7-14 days Decline in incidence and severity in last 10 years.	Isolation of patient for at least 2-3 weeks. Chloramphenicol, tetracyclines, and penicillin--but chiefly for prevention and treatment of complications. Pertussis vaccine followed by booster during an epidemic--vaccine can be given as early as 1½ to 3 months.

Table III-I (6)

BACTERIAL DISEASES COMMON TO MAN AND ANIMALS

Disease	Causative Organisms	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
anthrax[a] (splenic fever)	Bacillus anthracis	all animals to some degree: cattle, horses sheep, goats most common man and swine have greater natural resistance dogs, cats, birds, frogs, toads, and wild animals of prey under certain conditions mice, guinea pigs, rabbits are highly susceptible rats highly resistant	contaminated fodder, artificial foodstuffs, bites of contaminated flies, infected meat, drinking from contaminated pools, contaminated wool or bones from dean animals.	rapidly fatal peracute: cattle, sheep goats--cerebral apoplexy acute and subacute: cattle, horses, sheep fever, excitement then depression, stupor, spasm chronic: mainly in swine local lesions on tongue and throat	strict quarantine, prompt disposal of dead animals, destruction of manure, antianthrax serum, penicillin, Terramycin, vaccination of well, exposed animals, change of pastures, disinfecting
swine erysipelas (diamond skin disease)	Erysipelothrix insidiosa	hogs swine turkey sheep birds fish insects man (erysipeloid)	contact with fish, infected animals, or animal products (bones, meat, hides, manure)	acute, subacute, chronic: septicemia, reddish to purplish rhomboid spots on skin (diamonds) arthritis endocarditis (chronic more noted for crippling effect than for deaths (death losses can run from 0 to 75%)	anti-bacterial, serum, sulfonamides, penicillin

(a) Sometimes referred to as charbon and milzbrand in animals and as a malignant pustule and woolsorter's disease in people. In man disease is usually a localized infection.

TABLE III-1 (7)

BACTERIAL DISEASES COMMON TO MAN AND ANIMALS

Disease	Causative Organisms	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
brucellosis (undulant fever)	Brucella[a] Br. melitensis Br. abortus Br. suis	sheep goats (low incidence cattle swine[b] man--susceptible to all three species other species[c]	mainly through alimentary tract; aborted fetuses, placental membranes and fluids discharged teem with Brucella, cows may lick materials or ingest contaminated grass or water, Brucella may enter through the skin and mucous membranes (i.e. eyes and nostrils) and genitalia	udder, uterus, testicles, seminal vesicles, lymph glands and spleen most often, lameness and posterior paralysis noticeable in some swine, greatest losses due to abortions, decreased milk supply and sterility in man: weakness, generalized aches and pains, nervousness, enlarged lymph nodes about the neck, enlargement of spleen in more severe cases; occasional reports of abortion and sterility	Vaccination of cattle, principles of sanitation, good herd management, isolation and slaughter of herds. Avoid contact with infected animals, do not consume improperly cooked animal products or unpasteurized milk and milk products Treatment in cattle has not been successful, antibiotics tend to depress the infection only temporarily

(a) Although each of the three species of Brucella is relatively specific for individual species of animals, all can produce infection in other species and people.

(b) Infected swine herds are the last main brucellosis reservoir of concern to health officials. The National Brucellosis Committee was organized in 1948 to support the State-Federal bovine brucellosis eradication program and its success in reducing the incidence of bovine brucellosis has resulted in a sharp drop in the number of human cases. In 1960, 65% of the human brucellosis reported in the United States was thought to be of swine origin.

(c) Brucellosis of other species of animals is important from the standpoint that they may be potential transmitters to cattle, swine and goats.

Table III-1 (8)

BACTERIAL DISEASES COMMON TO MAN AND ANIMALS

Disease	Causative Organisms	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
leptospirosis(d)	*Leptospira pomona*	cattle swine sheep goats	carriers disseminate *Leptospira* through the urine; contact with contaminated waters	in cattle, sheep and goats: loss of appetite, fever, blood in urine, anemia, abortion	practical segregation and sanitary measures; Terramycin and dihydrostreptomycin, reduce urinary discharge; vaccination in animals (effective for 6 to 9 months) does not give protection for all serotypes
	L. sejroe	rodents			
	L. canicola	dogs (can be transmitted to man and cattle)		in hogs: icterus, frequent urination, conjunctivitis, hind leg weakness, stiffness, drowsiness, fever, nervous and digestive upsets	
Weil's disease	*L. icterohaemorrhagiae*	all	*Rattus norvegicus*	in dogs: muscular stiffness, thirst, vomiting, bloody diarrhea, weakness	(as above)
	L. grippotyphosa	livestock(e)			
				In man: liver & kidney disease nervous disorders (*L. icterohaemorrhagiae*--- hepatitis) (*L. pomona* & *canicola*---- meningitis)	

(d) All serotypes of leptospira known to infect animals may also infect man causing such diseases as Weil's disease, various field fevers, harvest fever, mud fever, Swineherd's disease.

(e) In horses, general symptoms of leptospirosis may be lacking but periodic ophthalmia may be due entirely to leptospirosis.

Table III-1 (9)

BACTERIAL DISEASES COMMON TO MAN AND ANIMALS

Disease	Causative Organisms	Animal (s) Affected	How Transmitted	Effect	Prevention and Treatment
Tularemia (rabbit fever)	*Pasteurella tularensis*	Mammals, esp. rodents, man (hunters & people who clean game), wild rabbits.	Deer flies (*Chrysops discalis*) most important fly in transmission, ticks, lice, fleas, cannibalism among wild animals; handling the carcass or eating undercooked flesh of infected animals; can be air-borne. Penetrates unbroken skin.	In man there are 6 clinical types; ulceroglandular; occuloglandular; typhoidal, pulmonary, ingestion, some rare forms are frequently fatal, invading organisms multiply locally and are transported to regional lymph nodes which become enlarged	Immunization rubber gloves when cleaning and dressing animals Streptomycin, aureomycin, some sulfa drugs, chlortetracycline, chloramphenicol

Table III-1 (10)

BACTERIAL DISEASES IN ANIMALS

Disease	Causative Organisms	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
Johne's Disease (paratuberculosis)	*Mycobacterium paratuberculosis*	cattle sheep goats	spread by droppings of infected animals	loss of appetite, diarrhea, emaciation, anemia and weakness incubation period long and progress of disease is slow but invariably fatal (yearly death loss may vary from 2 to 10 % in a herd)	calves more easily infected so should be reared in separate quarters--no exchange of equipment, no medicinal treatment successful, entire flocks are sometimes slaughtered
pasteurellosis (swine plague)	*Pasteurella multocida*	swine	sudden change in food or in environment may precipitate an acute epidemic	abnormalities of the respiratory system also known as hemorrhagic septicemia characteristic symptom is pneumonia mortality is about 20%	vaccination, antiserum, combinations of antibiotics

Table III-I (11)

BACTERIAL DISEASES IN ANIMALS

Disease	Causative Organisms	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
mastitis	Streptococci: *Streptococcus agalactiae*, *S. dysgalactiae*, *S. uberis* Staphylococci: *Micrococcus pyogenes* *Escherichia coli* *Aerobacter aerogenes* *Pseudomonas aeruginosa* *Pasteurella multocida* Yeast and acid-fast bacilli	Cattle Swine Sheep	on hands of milkers or on teat cups of machines flies contaminated bedding or floors	inflammation of the udder	proper diagnosis, sanitation and management in conjunction with drugs in combinations (antibiotics and sulfanamides) all infected cows should be milked last
	Corynebacterium pyogenes	found to affect non-lactating cows only			
vibriosis	*Vibrio fetus*	cattle	during coitus	infertility abortion (responsible for approx. 40%)	any treatment should be considered experimental--more practical to treat valuable bulls only
		sheep	has not been determined	abortion	definite recommendations cannot be made
pullorum	*Salmonella pullorum*	chickens, turkeys may strike ducks, sparrows, quail, bittern, geese, doves, etc.	main reservoir of infection is egg-producing organs of hen; transmitted from hen to chick or poult through the egg unsanitary conditions cause spread	lack of appetite, extreme depression, heavy breathing, diarrhea, paleness of comb increased water consumption, heavy death losses (may run as high as 80 or 90% of the brood) decreased productivity	whole-blood test breaking cycle of transmission, sanitation and disinfection, sulfamethazine, sulfamerazine, sulfaquinoxaline, furazolidone

Table III-2

RICKETTSIAL DISEASES OF MAN

DISEASE	ORGANISM	VECTOR	RESERVOIR	INCUBATION	PREVENTION
Typhus Fever Epidemic, European or Classical Typhus; Jail Fever	*R. prowazekii*	Louse	Man	6-15 days	Delouse people and clothes
Typhus Fever Endemic or Murine Typhus	*R. typhi*	Rat flea (but louse can be involved causing epidemic)	Rat	6-14 days	Control rat population Delousing
Rocky Mountain Spotted Fever	*R. rickettsii*	Wood tick	Wild rodents	3-10 days	Remove and destroy ticks without crushing them on body. Clear and burn vegetation in infested areas; destroy animals with ticks.
Tsutsugamushi Scrub Typhus	*R. tsutsugamushi*	Mite (chigger)	Field mice and rats	7-10 days or even 21 days	Mite-proof clothing, anti-mite powders & fluids on clothes Burn shrub around campsites
Q Fever	*R. burnetii*	Wood tick Cattle tick	Wild rodents Cattle, sheep and goats	2-3 weeks	Pasteurization of milk and inspection of imported animals
Rickettsialpox	*R. akari*	Mouse mite	House mice	10-24 days	Eliminate rodents
Trench Fever	*R. quintani*	Body louse	Man		Delousing
Fièvre Boutonneuse	*R. conorii*	Dog tick	Wild rodents		

RICKETTSIAL DISEASES IN GENERAL

Transmitted to man by arthropods—usually through contaminated feces on skin or from a bite.
(Q Fever can be transmitted by direct contact with animal resevoirs)
Air-borne transmission possible but not common

Immunity after an attack usually exists for some time but is not permanent.

Treatment — tetracyclines and chloramphenicol

Vaccines exist which modify course of disease—give varying degrees of protection.

Table III-3 (1)

MALARIA — **PROTOZOAL DISEASES OF MAN**

VECTOR	PROTOZOA SOURCE OF INFECTION & MODE OF TRANSMISSION	FOUND
Female *Anopheles* mosquito (to man)	Infected mosquitoes and men.	
	Plasmodium vivax--benign tertial malaria (most common type, but withstands therapy and remains chronic)	Tropic, temperate zones
Culex and *Aedes* transmit malaria to birds	*P. falciparum*--malignant tertian malaria	Tropics, subtropics
	P. malariae--quartan malaria (minor disease except in tropical Africa)	Tropical Africa
	P. ovale--ovale malaria (milder form of tertian malaria)	Primarily Cen. East Africa
	Mosquito bites healthy man and injects Plasmodium sporozoites into the blood stream. The sporozoites move from the blood stream into the tissues where they form trophozoites (the vegetative stage of protozoa) which return to the blood stream and invade the erythrocytes. Here asexual reproduction takes place, and the trophozoites develop into gametocytes. Another mosquito bites the infected man and ingests the gametocytes which now reproduce sexually forming sporozoites.	

PREVENTION & TREATMENT

Control: elimination of breeding places of *Anopheles* mosquito. Screen & spray dwellings.

Preventive drugs: Anti-malarial drugs Suppressive drugs in military to allow a low-grade infection and therefore some immunity.

Anti-malarial drugs

1. Suppressives: chloroquine and amodiaquin (eliminate asexual blood phase)
2. primaquine--must be used with other drugs. Can cure vivax malaria but not active in eliminating blood parasite. (Has replaced pentaquine & isopentaquine.)
3. pyramethamine--"Daraprin" most recent. A suppressive prophylactic to vivax and falciparum. Also effective against quartan. Only suppresses acute stages slowly--must be supplemented with chloroquine, amodoquine, quine or quinacrine.

Table III-3 (2)

PROTOZOAL DISEASES OF MAN

DISEASE	CARRIERS	CAUSE, SOURCE & TRANSMISSION OF INFECTION	SUSCEPTIBILITY IMMUNITY & INCUBATION	PREVENTION & TREATMENT
Dysentery	Housefly, convalescents & occasional healthy carriers	(1) Entamoeba histolytica most common human form	No immunity	Treat: emetive hydrochloride is specific (alkaloid of ipecacmanha) injections control acute disease. To get rid of cysts requires emetine bismuthous iodide which releases emetine on ulcers. Tetracyclines for (2).
		(2) Balantidium coli lives in intestines of swine--man ingest cysts	may be long latency (1 year)	
	Mosquitoes	(3) Plasmodium falciparum Malarial dysentery		
	Sandfiies (dogs and cats are reservoirs)	(4) Leishmania donovani Leishmanial dysentery (tropical)		
		Spread by contact with contaminated food and water. Organisms expelled in feces.		

Table III-4 (1)

SERIOUS

VIRAL DISEASES OF MAN

DISEASE	CARRIERS	SOURCE, CAUSE & TRANS-MISSION OF INFECTION	IMMUNITY SUSCEPTIBILITY INCUBATION	PREVENTION & TREATMENT
Yellow Fever	Mosquitoes: Female *Aedes aegypti* vector of urban yellow fever. Specific species of *Aedes* for either man to man or monkey to man transmission in S. America or Africa.	Blood of infected persons, monkeys & probably other wild animals Mosquito bites infected person 10-12 days later bites healthy person Attacks liver→jaundice or even hemorrhage in severe cases Viscerotropic but bad vaccine can cause neurotropic infection	Permanent acquired immunity. 3-6 days after bite	Control of mosquito breeding places Keep patients away from mosquitoes during first 5 days of illness. Vaccination: 17D strain Law: anyone coming from or passing through yellow fever zones of Africa, Cen. or S. Am. must be vaccinated within 6 years although immunity lasts longer. No specific treatment
Polio-myelitis (Infantile paralysis) 3 types	Healthy humans	Virus lives in gastrointestinal tract--enters body via respiratory tract. May eventually enter CNS Virus in contaminated milk, water, pools, food, sewage Flies and insects transport Can be: spinal, respiratory, bulbar	Children and pregnant women most susceptible Permanent immunity for specific type after attack. 7-14 days	Avoid crowds, fatigue, surgery, vaccinations during epidemics. No specific treatment Vaccination: Salk, Sabine, Koprowski
Smallpox (Variola major)		Variola virus Highly contagious Airborne droplets from nasopharynx, contaminated articles, dried scales Damage to skin, eyes & ears but not to CNS	Immunity after attack. 7-16 days	Penicillin or broad spectrum antibiotics to prevent secondary bacterial infection. Vaccination every 5-7 years or every 3 in the event of an epidemic

Varioloid: mild form of disease contacted by people once vaccinated but whose immunity has decreased.
Virus of varioloid is virulent enough to cause variola major in unvaccinated people.

Table III-4 (2)

COMMON CONTAGIOUS, CHILDHOOD

VIRAL DISEASES OF MAN

DISEASE	CAUSE, SOURCE & TRANSMISSION OF INFECTION	IMMUNITY SUSCEPTIBILITY INCUBATION	PREVENTION & TREATMENT
Chickenpox	Along with measles--highest rate of communicability. Communicable eve- before eruption is evident. Droplet spray from nose and throat and freshly soiled articles.	Permanent immunity after attack. 70% of pop. has disease before 15 yrs. of age. 2 to 3 weeks	Isolation of patient usually required by health dept. Convalescent serum helpful in protection after exposure Antipruritic lotion or powder for itch.
German Measles (Rubella)	Less contagious than measles Droplet spray + soiled articles	Permanent immunity after attack. 14 to 21 days	No curative drug No vaccine
Measles (Rubeola)	Highly contagious Droplet spray + soiled articles	Fever--10 days after exposure Rash--13-15 days Permanent acquired immunity	Antibiotics and sulfa drugs only for complications Convalescent serum for protection or modification, Gamma globulin which has antibodies for measles virus gives passive immunity for 3 - 6 weeks Vaccine still being tested
Mumps (Infectious parotitis)	Virus in saliva--droplet spray and contaminated articles Parotid glands--usually both 10% of cases have some CNS involvement Virus can be in blood and spinal fluid even when CNS not involved	Second attacks in 7-10% of cases 12 to 26 days	No specific treatment for children Mouth must be kept clean to avoid secondary bacterial infections Vaccine for adults, esp. males--but does not give lasting immunity

Table III-4 (3)

ENCEPHALITIS **VIRAL DISEASES OF MAN**

(Any condition characterized by inflammatory and degenerative lesions of the brain and cord)

I. **Arthropod-borne Encephalitides**

St. Louis encephalitis, equine encephalomyelitis (Western and Eastern types) -- only ones in U.S.
Venezuelan equine, Japanese B, Russian spring-summer, Murray Valley encephalitis

Man is accidental host
Mosquitoes are vectors and ticks pass virus on to next generation

II. **Encephalitis Lethargica**

Also called Von Economo's encephalitis or Epidemic encephalitis
Most prevalent in 20 - 30 year-old group
Epidemic in U.S. from 1919 to 1926.
May have chronic phase directly after acute attack or may not occur for 15 years.

III. **Postinfectious Encephalomyelitis**

May follow measles, German measles, chickenpox, smallpox, vaccination and antirabic treatment.

IV. **Miscellaneous Virus Encephalomyelitides**

Other viruses producing encephalitis at times are : herpes simplex, lymphogranuloma venereum, lymphocytic choriomeningitis, mumps, poliomyelitis, Coxsackie and ECHO viruses.

V. **Guillain-Barre Syndrome**

Often follows acute respiratory infections

MORTALITY & SEQUELAE

Fatality varies from 5 - 50% II -- 20-40%; III and IV -- 5-30%; Eastern equine -- 50%.

Sequalae of mental deterioration, convulsions for children and Parkinson syndrome for adults, esp. after II.
Except for infants, the majority of survivors in other groups do not develop sequalae.

TREATMENT

No specific treatment for any of these variations, except lumbar puncture to relieve increased pressure of cerebrospinal fluid.

Table III-4 (4)

MISCELLANEOUS — VIRAL DISEASES OF MAN

DISEASE	CAUSE, SOURCE & TRANSMISSION OF INFECTION	IMMUNITY SUSCEPTIBILITY INCUBATION	PREVENTION & TREATMENT
Influenza	Highly contagious Droplet spray Inflammation of respiratory tract	Active immunity against specific virus for about 1 year. 24 to 72 hours	No specific treatment except for the complications. Vaccination for specific strain helpful for a while but not always effective.
Pneumonia (Viral)	Sometimes caused by adenoviruses		Tetracycline and chloramphenicol used but may not be effective.
Ornithosis (Psittacosis)	Inhalation of virus from infected birds (feathers, dust) or droplets from human patients Symptoms similar to pneumonia	7 to 14 days	Tetracycline antibiotics Regulation of traffic in parrot family birds, esp. imports Destroy infected bird; disinfect house.
Hepatitis	Inflammation of the liver; jaundice		
Type A (Infectious hepatitis)	Virus in feces, contaminated food or water. Person to person, esp, in crowding	2 to 6 weeks	Bed rest and diet high in proteins and carbohydrates Gamma globulin gives some immunity for 1 or 2 months after exposure.
Type B (Homologous serum hepatitis)	Injection of infected human blood (transfusions, serum, certain vaccines) Improperly sterilized instruments Virus not present in feces	2 to 5 months (but can be 2-4 weeks) No cross immunity with Type A	Bed rest and diet high in proteins and carbohydrates Sterilization of instruments Allow blood plasma to sit at room temperature for 6 months

Table III-4 (5)

VIRAL DISEASES IN ANIMALS

Disease	Causative Organism	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
Newcastle disease	Tortor furens	chickens, turkeys, other domestic poultry and wild birds man	virus present in apparently healthy carriers	death losses may be as high as 100% among young chickens average 30 to 40%; turkey poults 15 to 20%; among laying birds usually low but may be as high as 80%. In man a mild disease causing inflammation of one eye respiratory-nervous disorder in chickens and turkeys	vaccination coupled with sound sanitary management
myxomatosis (mosquito disease)	Molitor myxomae	rabbits	mosquitoes by carrying blood or exudate from the eye or nostril of affected animal to non-infected rabbit, direct contact, biting flies and fleas	rapidly fatal characterized by tumors around the eyes, nose, mouth and sex organs--central nervous system is affected mortality may be as high as 95% in animals over 60 days old	early recognition and immediate destruction of all animals with symptoms screening units, reducing mosquito populations by drainage and spraying

Table III-4 (6)

VIRAL DISEASES IN ANIMALS

Disease	Causative Organism	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
hog cholera	Virus which can be destroyed in 60 minutes in a 2% cresol solution	swine	man most to blame: improper handling during vaccinating time, must disinfect shoes, truck and change clothing after visiting sales barns, stock yards or slaughter houses feed contaminated with urine of infected animals scraps of uncooked pork	viremia or blood infection symptoms vary in different hogs and herds in acute cases hogs die quickly, rarely recover from chronic type--death losses very high	no dependable treatment available; prevention is of prime importance through proper sanitation, disinfecting, cooked garbage, modified live virus vaccines
lymphomatosis (leucosis)	submicroscopic agents believed to be virus	chickens		tumerous accumulations of lymphoid cells	no vaccines or prophylactic measures, no chemotherapeutics, antibiotics or other treatments are known to be effective in the cure;
			by contact through the hatching egg	visceral: (big liver disease) listless, droopy, comb shrivelled, uric acid and bile pigments on abdominal feathers	isolation and quarantine procedures during hatching and brooding periods
			contact with infected environment during early brooding period	neural: (fowl paralysis) spraddling position, weakness, lack of coordination, respiratory distress or digestive tract upsets depending on nerves involved	
				ocular: (gray eye) impairment of vision or complete blindness in one or both eyes	

Table III-4 (7)

VIRAL DISEASES IN ANIMALS

Disease	Causative Organisms	Animal(s) Affected	How Transmitted	Effect	Prevention and Treatment
bloat	due to some dysfunction of the eructating mechanism theories as to cause: physical, biochemical, hereditary and as connected with soil fertility and climate	cattle sheep goats	many theories (e.g. saponis found in highest concentration in legumes have effect on surface tension)	distension of the stomach with gas: swelling limited to the rumen (paunch) and reticulum (honeycomb) death losses are high	use of mixed pastures and feeding of course non-leguminous roughage daily defoaming agents in non-critical stages; emergency rumenotomy in acute cases; stomach tube
bovine shipping fever	exact cause of this disease is not known; comparable clinically to influenza in man (probably viral)	cattle	usually associated with the shipping of animals	decrease in weight and 20% mortality infectious respiratory disease fever, chilling, soft cough, watery discharge from nose and eyes	avoid hard driving allow ample time for rest; avoid overcrowding and over handling; recently shipped cattle should be kept apart; watering tanks should be cleaned often; remove dead animals promptly provide prompt antibiotic therapy

ANNEX C

(to Chapter III § 3)

Table III - 6 (1)

PESTS ON LEGUMINOUS CROPS, FIELD CROPS (corn, peanuts, beans, potatoes, alfalfa, sorghums, etc.)

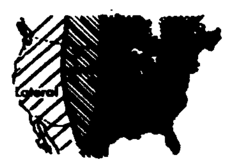
Insect	Scientific Name	Climate Area	Crops	Control and Treatment
alfalfa caterpillar	*Colias philodice eurytheme*	Southwest & Pacific Coast States Arizona & California particularly	alfalfa	methoxychlor wilt disease, insect enemies, laboratory prepared virus disease of the caterpillar, spore-forming bacterium, Bacillus thuringiensis
spittlebug	*Aphrophora spp.*	Eastern & North Central States	alfalfa clover	benzene hexachloride, lindane, toxaphene on crops grown for seed purpose; methoxychlorotenone on crops grown for hay
potato leaf hopper	*Empoasca fabae*		alfalfa peanuts potatoes	methoxychlor on alfalfa, sulphur, & DDT on peanuts
tobacco thrips	*Frankliniella fusca*		tobacco peanuts	DDT, aldrin, dieldrin
southern corn rootworm (larva of the spotted cucumber beetle)	*Diabrotica undecimpunctata howardi*	South	corn peanuts	chlordane at planting time
pea aphid	*Macrosiphum pisi*	early spring	alfalfa peas	DDT and parathion in solution but not to alfalfa fields in blossom
garden webworm	*Loxostege similalis*	late summer early fall	alfalfa	prompt cutting, calcium arsenate, toxaphene insecticides on alfalfa grown for seed only

Table III - 6 (2)

PESTS ON LEGUMINOUS CROPS, FIELD CROPS (corn, peanuts, beans, potatoes, alfalfa, sorghums, etc.) (con't)

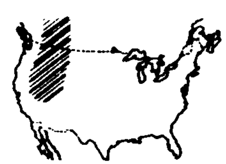
Insect	Scientific Name	Climate Area	Crops	Control and Treatment
lygus bug	Lygus hesperus Lygus elisus Lygus lineolaris	west	seed alfalfa other field crops and weeds	DDT, toxaphene, etc.
chinch bug	Blissus leucopterus		corn sorghum small grains, esp. barley grasses	resistant species, rotation; poisoned barriers; insecticides
white grubs (May beetles)	Family Coccinellidae	N.E., N-central	corn potatoes soybeans grasses	rotate with clovers; alfalfa and legumes; lead arsenate, chlordane
onion thrips	Thrips tabaci	N and S (wherever onions grow)	onions alfalfa clover	DDT
cutworms	Chorizagrotis auxiliaris		small grains peanuts legumes	poisoned bran bait
Mormon cricket	Anabrus simplex	Rocky Mts.	alfalfa range grasses dry land wheat	poison bait (sodium fluosilicate)
grasshopper	Melanoplus spp.	 especially semi-arid lands	alfalfa, range vegetation corn, etc.	sprays: DDT, toxaphene aldrin, chlordane

Table III - 6 (3)

PESTS ON LEGUMINOUS CROPS, FIELD CROPS (corn, peanuts, beans, potatoes, alfalfa, sorghums, etc.)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
European corn borer	Pyrausta nubilalis		corn	cultural methods, insecticides (?) 6 species of parasites
corn earworm	Heliothis armigera		sweet corn	hot dry windy weather; lady beetles, benzene hex., DDT
fall armyworm	_phygma frugiperda	Corn Belt, central and eastern states	corn alfalfa cotton peanuts grasses weeds	DDT, TDE, Toxaphene
white-fringed beetle	Graphognathus leucoloma	S.E. U.S. Fla., Ala., Ga., Tenn., S. Carolina, Miss., La.	soybeans cotton corn peanuts potatoes weeds, etc.	rotation--cultural methods DDT
alfalfa weevil	Hypera postica	Utah	alfalfa	clean cutting prompt removal of hay DDT control seed: dieldrin, chlordane parathion hay: calcium arsenate methoxychlor Bathyplectes curculionis (parasite from Italy)

Table III - 6 (4)

PESTS ON LEGUMINOUS CROPS, FIELD CROPS (corn, peanuts, beans, potatoes, alfalfa, sorghums, etc.)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
corn flea beetle	*Chaetocnema pulicaria*		field corn	DDT
red harvester ant	*Pogonomyrmes barbatus*	Southwestern States	alfalfa	dieldrin, chlordane and methyl bromide
sugarcane borer	*Diatraea saccharalis*	Gulf states, Florida	sugarcane corn sorghum	cryolite dust, dust containing 40% ryania
two-spotted spider mite	*Tetranychus bimaculatus*	throughout Cotton Belt	seed alfalfa during blooming period	sulphur alone or as diluent of DDT
rice weevil	*Sitophilus oryza*	south	corn	DDT, toxaphene, benzene hexachloride and dieldrin
corn leaf aphid	*Rhopalosiphum maidis*		corn	DDT, et. al.
northern corn rootworm	*Diabrotica longicornis*	north	corn	"
southern corn rootworm	*Diabrotica undecimpunctata howardi*	south	corn	"
sap beetle	*Glischrochilus q. quadrisignatus*		corn	"
fungus beetles	*Carpophilus spp.*		corn	"
sorghum midge	*Contarinia sorghicola*	Gulf states	sorghum	DDT, aldrin
sorghum webworm	*Celama sorghiella*	humid areas	sorghum	DDT, et. al.

Table III - 6 (5)

COTTON PESTS

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
boll weevil	*Anthonomus grandis*	all cotton areas, mild winters, cool damp summers preferred	cotton	early planting and picking; early destruction of cotton stalks; benzene hexachloride
bollworm (tomato fruitworm (corn earworm	*Heliothis armigera*	all cotton areas, esp. Texas, Okla., La.	cotton corn tomatoes	hot dry windy weather lady beetles, DDT, benzene hexachloride
cotton aphid (cotton louse (melon aphid	*Aphis gossypii*	all over U.S.	squash melons cucumbers, etc. cotton	lady beetles, etc. many insecticides
cotton fleahopper	*Psallus seriatus*	all cotton areas, ésp. Texas, Okla., La.	cotton (weeds)	insecticides (sulfur)
cotton leafworm	*Alabama argillacea*	as season progresses from South Texas north	adults- peaches, grapes, etc. larvae- cotton	arsenic compounds DDT and toxaphene
pink bollworm	*Pectinophora gossypiella*	Okla., La., Fla., Texas, Ariz., N.M.		cultural methods, DDT
spider mites (7 species)		all cotton belt, hot dry weather preferred	cotton (weeds)	heavy rain; cultural methods; sulfur, TEPP

Table III - 6 (6)

COTTON PESTS

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
stinkbugs (southern brown (southern green (say (conchuela	Euschistus servus Nezara veridula Chlorochroa sayi Chlorochroa ligata		cotton	DDT, toxaphene, benzene hexachloride plus sulfur
white-fringed beetle (adult stage)	Graphognathus leucoloma striatus	Ala., Fla., Ga., La., Miss., No. & So. Caro., & Tenn.	cotton	heavy commercial fertilization
grasshoppers	Melanoplus spp.		cotton	benzene hexachloride
thrips	Order Thysanotera		cotton	DDT
tarnished plant bug	Lygus oblineatus		cotton	DDT
rapid plant bug	Adelphocoris rapidus		cotton	DDT

Table III - 6 (7)

PESTS ON GRAINS (wheat, barley, rye, oats)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
chinch bug	*Blissus leucopterus*	damp, shade	small grains especially barley	grow immune or resistant crops; rotation; poisoned barriers; insecticides such as nicotime, rotenone, sabadilla, DDT, chlordane and toxaphene
wheat stem sawfly	*Cephus cinctus*	N. Great Plains Montana North Dakota	wheat rye barley, oats, flax } to a lesser extent	cultural methods;* crop rotations; no insecticide control
Hessian fly	*Phytophage destructor*	winter wheat region	wheat barley rye	cultural methods, e.g. plow under stubble of last crop, prepare good seed bed, maintain high fertility; rotation
wheat jointworm	*Itarmolita tritici*	E. of Mississippi River plus Mo., Ia., Utah, Ore., Calif.	wheat	cultural methods, e.g. plow stubble under; insecticide control not practical
wheat midge	*Sitodiplosis mosellana*	Pacific Northwest spring	wheat	crop rotation, cultural methods, e.g. plow stubble under
pale western cutworm	*Agrotis orthogonia*	Northern and Southern Great Plains	wheat	spring starvation, crop rotation

* e.g., early harvesting, cutting grain before quite ripe, salvage fallen stems, deep plowing in spring, leave stubble on surface, etc.

Table III - 6 (8)

PESTS ON GRAINS (wheat, barley, rye, oats)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
greenbug	*Toxoptera graminum*	spring early summer Central & Southeastern States	small grains	parathion above 45° F., tetraethyl, phosphate above 70° F.
corn flea beetle	*Chaetocnema pulicaria*		wheat corn	DDT
English grain aphid	*Macrosiphum granarium*	fall and spring cool weather	small grains	DDT
apple grain aphid	*Rhopalosiphum fitchii*	"	"	"
rice stink bug	*Oebalus pugnax*	southern states	rice	DDT

PESTS ON GARDEN CROPS (VEGETABLES)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
beet leafhopper (carries virus disease: curlytop)	*Circulifer tenellus*	western U.S.-- arid and semi-arid	sugar beets beets beans tomatoes melons, etc. (weeds)	control weeds plant grass DDT
Pacific coast wireworm (click beetles)	*Limonius canus*	irrigated lands west coast	all garden and field crops	treat soil with DDT

Table III - 6 (9)

PESTS ON GARDEN CROPS (VEGETABLES)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
harlequin bug (collard bug, fire bug, calico bug, etc.)	*Murgantia histrionica*	south	horse radish cabbage broccoli kale turnip collards	clean fields; sabadilla-seed, rotenone, pyrethrum
striped cucumber beetle	*Acalymma vittata*	east and central United States	cucumber squash melon	derris, cube, cryolite (50% sodium fluoaluminate)
imported cabbage worm	*Pieris rapae*	U.S.	broad leaves: cabbage brocolli cauliflower collards	rotenone pyrethrum (less effective) DDT
squash vine borer	*Melittia cucurbitae*	U.S.	squash melons pumpkins, etc.	rotenone, nicotine sulfate, early and repeated treatment
tomato fruitworm (corn earworm, bollworm)	*Heliothis armigera*	all U.S. Southern States California	tomatoes	TDE, corn meal bait containing cryolite
sweet potato weevil	*Cylas formicarius elegantulus*	south	sweet potatoes	cultural methods; rotation-DDT
seed corn maggot	*Hylemya cilicrura*	cool, wet preferred organic fert.	sprouting seeds of beans, corn peas potatoes	no organic fert.; plant in warm soil; treat seed with chlordane
pea weevil	*Bruchus pisorum*	U.S.	dry peas	DDT, rotenone, methoxychlor

Table III - 6 (10)

PESTS ON GARDEN CROPS (VEGETABLES

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
tuber flea beetle	*Epitrix tuberis*	Washington, Ore., Colo., Neb.	potatoes	DDT
onion thrips	*Thrips tabaci*	U.S.	onions alfalfa clover (weeds)	DDT
clay-backed cutworm	*Agrotis gladiolus*	east of Rocky Mts.	young plants garden crops	sodium fluosilicate, Paris green, DDT
pea aphid (carries virus disease)	*Macrosiphum pisi*	U.S.	garden peas alfalfa clover	rotenone DDT
tobacco hornworm (rel. tomato hornworm)	*Protoparce sexta*		tomato tobacco	parasitic wasp: (*Apanteles congregatus*) TDE, calcium arsenate
squash bug	*Anasa tristis*		pumpkin squash melons, etc.	tachinid fly: (*Trichopada pennipes*) dust with sabadilla seed powder
corn earworm	*Heliothis armigera*	all cotton areas esp. Texas, Okla., La.	cotton corn tomatoes	hot dry windy weather lady beetles DDT, Benzene hexachloride
Mexican bean beetle	*Epilachna varivestis*		beans	derris, cube, cryolite dust or spray
Colorado potato beetle	*Leptinotarsa decemlineata*		potatoes	DDT

Table III - 6 (II)

PESTS ON GARDEN CROPS (FRUIT)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
Japanese beetle	Popillia japonica		275 plants	Milky disease* DDT, lead arsenate, derris powered
Oriental fruit moth	Grapholitha molesta	all over U.S. esp. east and midwest	quinces peaches other deciduous fruits	DDT, parathion
apple maggot (railroad worm)	Rhagoletis pomonella	N.E. and midwest	apples	DDT, lead arsenate
codling moth (apple worm)	Carpocapsa pomonella		apples pears quinces walnuts	DDT, lead arsenate
plum curculio	Conotrachelus menuphar	E. of Rocky Mts.	plums peaches cherries apples	DDT, lead arsenate
orchard mites two-spotted spider mite European red mite	 Tetranychus bimaculatus Paratetranychus pilosus	hot dry weather pref. all over U.S.	fruit trees	spray early with oil, insecticides
Forbes scale	Aspidiotus forbesi	midwest all over U.S.	fruit trees	oil, parathion

* Bacillus popilliae, a germ disease of Japanese beetle grubs forming spores which can be artificially processed to make a spore-dust powder available commercially.

Table III - 6 (12)

PESTS ON GARDEN CROPS (FRUIT)

Insect	Scientific Name	Climate Area	Crops	Control and Treatment
citrophilus mealybug	*Pseudococcus gahani*	California	citrus	Australian lady beetle, parasites
Comstock mealybug	*Pseudococcus comstocki*	Northeastern states	apples	parasites
citrus mealybug	*Pseudococcus citri*	California	citrus	Australian lady beetle DDT, chlordane
long-tailed mealybug	*Pseudococcus adonidum*	"	"	"
citrus blackfly	*Aleurocantus woglumi*	east and west coast borders	citrus	Parasite: *Eretmocerus surius* Predatory beetle: *Catana clauseni*
black scale	*Saissetia oleae*	California	citrus	Parasite: *Metaphycus helvolus* fumigant (HCN)
wooly apple aphid	*Eriosoma lanigerum*	U.S. apple growing areas, Pacific Northwest	apples	Parasite: *Aphalinus mali*

Table III - 7 (1)

PESTS ON LIVESTOCK

Insect	Scientific Name	Climate Area	Animal (s) Attacked	Control & Treatment
screw-worm fly	*Callitroga hominivorax*	Texas, Central and North Central States	cattle hogs sheep goats	EQ 335 Screw-worm Remedy Smears 62 and 82 sterilization
cattle grubs (heel fly) common		all U.S.	cattle	rotenone only
northern		Eastern, Middle Northern and Northwestern		
horn fly	*Siphona irritans*		cattle	DDT, toxaphene (beef) pyrethrum or methoxychlor (dairy) TDE
stable flies	*Stomoxys calcitrans*		cattle horses	destruction of breeding places, methoxychlor, lindane and pyrethrum. DDT
horse flies			cattle horses	no satisfactory method of control, repellents in use in 1952 not effective enough or too costly.
deer flies	*Chrysops discalis*		"	"
irrigation water mosquitoes		irrigated lands in western U.S.	cattle man	

Table III - 7 (2)

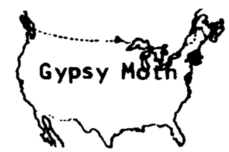
PESTS ON LIVESTOCK

Insect	Scientific Name	Climate Area	Animal(s) Attacked	Control & Treatment
ticks				
cattle tick	*Boophilus annulatus*	Texas (southern tip) south of Central America, along the Gulf of Mexico	cattle	arsenical materials
Gulf Coast tick	*Amblyomma maculatum*	along the Gulf of Mexico	all farm animals	toxaphene, lindane-DDT (not for dairy)
lone star tick	*Amblyomma americanum*	southern and lower midwestern states	all kinds livestock, wild animals and deer	"
ear tick	*Otobius megnini*		cattle, horses sheep and goats	"
winter tick	*Dermacentor albipictus*	southwest, midwest and north central states	horses	"
fowl tick (blue-bug)	*Argas persicus*	southern states, southwest	chickens and other poultry	treat cracks, crevices, etc. with creosote or carbolineum oils. DDT
lice*				
bloodsucking	Order *Diptera*		cattle, horses, goats, sheep, hogs	insecticides (DDT, TDE, toxaphene, chlordane on beef cattle) (derris or cube dusts containing rotenone on dairy animals) (DDT dips for hogs, sheep) (Lard on heads of poultry pinch of sodium fluoride) (DDT for horses)
biting	Order *Hymenoptera*		cattle, horses, goats, sheep, chickens	

* Lice of a particular species live on only one kind of animal or fowl.

TABLE III-8 (1)

FOREST PESTS

Insect	Scientific Name	Climate Area	Trees	Control and Treatment
Gypsy moth	Porthetria dispar		fruit forest and shade	DDT
Elm leaf beetle	Galeurcella xanthomelaena	Maine to N. Carolina, westward to Arkansas and Michigan, Idaho and Pacific Coast	Elm	DDT, lead arsenate, nicotine sulfate
red-headed pine sawfly	Neodiprion lecontei	eastern half of U.S., south to Missouri and Arkansas, eastern Canada	hard pines preferred conifers	DDT, lead arsenate
hemlock sawfly	Neodiprion tsugae Midd.	coastal forests of Washington and Oregon, portions of Idaho and Montana	western hemlock (primary host), also mountain hemlock, Pacific silver fir	several hymenopterous parasites (e.g. Delomerista diprionis Cush. and Itoplectis montana Cush. are two important ones) DDT
larch sawfly	Pristiphora erichsonii	Lake states (Minn., Wis., Mich.) cool, moist situations	tamarack, western larch (other larch species) eastern hemlock	parasites, insect and arachnid predators, fungal and bacterial disease, attack by vertebrates

insecticides such as benzene hexachloride, lindane, dieldrin, malathion, and lead arsenate used with extreme care near lakes, streams, etc.

TABLE III-8 (2)

FOREST PESTS

Insect	Scientific Name	Climate Area	Trees	Control and Treatment
elm leafhopper[a]	*Scaphoideus luteolus*	midwest	Elm	DDT
beech scale[b]	*Cryptococcus fagi*	northeastern states	beech	spraying with lime-sulfur on park trees, no proved control in forests
bark beetles[c] Engelmann spruce	*Dendroctonus engelmanni*	western Colorado	spruce	fuel or Diesel oil with orthodichoro-benzene or DDT
Black Hills	*Dendroctonus ponderosae*	Rocky Mountain region	pine	sanitation-salvage logging prompt clean-up or utili-zation of potential breeding places (slash, windfalls or fire-killed trees)
mountain pine	*Dendroctonus monticolae*	Rocky Mountain, Pacific Coast California	pine	
Douglas-fir	*Dendroctonus pseudotsugae*	U.S.	fir	"
sitka-spruce	*Dendroctonus obesus*	U.S.	spruce	"
southern pine	*Dendroctonus frontalis*	U.S.	pine	"
red turpentine	*Dendroctonus valens*	U.S.	pine	"

a. Transmits virus disease known as phloem necrosis.

b. Responsible for spread of nectria disease of beech, a beech-bark canker fungus, *Nectria coccinea* var. faginata.

c. *Dendroctonus* beetles are the most important group of tree killers.

TABLE III-8 (3)

FOREST PESTS

Insect	Scientific Name	Climate Area	Trees	Control and Treatment
black turpentine beetle	Dendroctonus terebrans	southern states	all southern pines chiefly slash and loblolly	spraying with BHC
fir engraver	*Ips pini*	U.S.	western hemlock, fir, engleman spruce	fuel or Diesel oil with orthodichoro-benzene or DDT fell-peel-burn method sanitation-salvage logging prompt clean-up or utilization of potential breeding places (slash, wind-falls or fire-killed trees)
native Elm[d]	*Hylurgopinus rufipes*	U.S., Canada	elm	DDT (removal of breed-ing material)
European Elm[d]	*Scolytus multistriatus*	U.S.	elm	DDT
poplar and willow borer[e]	*Cryptor hynehus lapathi*		willows, poplar coniferous	
spruce budworm	*Choristoneura fumiferana*	U.S., Canada Maine, Adirondacks	forests white spurce balsam fir	DDT; clear-cut mature and over-mature balsam stands; operate on short rotation; in-crease proportion of red and black spruce

d. Spread Dutch elm disease; *Scolytus multistriatus* more important.

e. Transmits a vascular disease of willow caused by *Pseudomonas saliciperda*.

TABLE III-8 (4)

FOREST PESTS

Insect	Scientific Name	Climate Area	Trees	Control and Treatment
wood lice[f]	Crustacea, Isopoda	warm, moist soil	young plants, roots	
Texas leaf-cutting ant (town ant)	Atta texana Buckley	east Texas west-central Louisiana	pine seedlings	fumigation with methyl bromide; dieldrin and chlordane dust
pine root collar weevil	Hylobius radicis Buchanan	New England south to Virginia, west to Minnesota and north to Ontario and Manitoba most severe on sandy, well-drained soils	jack pine Scotch pine (also attacks red pine, lodge-pole and ponderosa	carabid beetle, Pasimachus elongatus Lec. feeds on adults; avoid planting of highly susceptible hosts (i.e. jack pine and Scotch pine) on dry, sterile soils; dieldrin or lindane
pine reproduction weevil[g]	Cylindrocopturus eatoni Buch.	California, Oregon, areas of deficient soil moisture	juvenile trees in particular penderosa and Jeffrey pines; under planted conditions other species of pines have been attacked	several parasitic and predaceous enemies; development of resistant hybrids; DDT
lodgepole needle[h]	Recurvaria milleri	Califronia, southern Sierra Nevada	lodgepole pines chiefly but migrate to nearb conifers	many natural enemies and one disease (a granulosis virus); DDT ineffective; recent tests show some success in spraying with dieldrin, endrin or malathion in large quantities
black-headed budworm	Alceris variana	coast to coast in North America	several species of fir, hemlock and spruce	parasitic flies and wasps; virus disease; DDT

f. Land dwelling crustaceans akin to crabs rather than insects.

g. This insect has been responsible for the almost complete destruction of a 3,000 acre plantation of ponderosa in Jeffrey pines in the Big Springs area of the Lassen National Forest.

h. This insect usually works in combination with the mountain pine beetle, Dendroctonus monticolae, which attacks the weakened tree and kills it.

The forest teems with other insects which also damage trees and roots of plants: ants, scale bugs, aphids, springtails and mole crickets.

Table III-9 (1)

Table III-9 summarizes the more important beneficial insects both in regard to the species and the frequency and effectiveness with which they attack the insect pests of agricultural crops.

BENEFICIAL INSECTS

Insect (common name)	Scientific Name		Host or Prey
PREDATORS			
dragonflies	Suborder _Anisoptera_	Order Odonata (dragonflies, damselflies)	horse flies, mosquitoes and insects in the water
damselflies	Suborder _Zygoptera_		
lace wings, aphid-lions, golden-eyed flies	Family _Chrysopidae_	Order Neuroptera (lace wings, ant lions)	aphids and related insects
ant-lions or doodle bugs	Family _Myrmeleonidae_		ants
brown lacewings	Family _Hemerobiidae_		aphids, mealybugs, white flies, other small insects
snake flies	Family _Rhaphidiidae_		insects under bark of trees
mantid flies[a]	Family _Mantispidae_ _Mantispa brunnea_ (common American species)		_Lycosa_ spider or _Polybia_ wasps
predaceous beetles	Suborder _Adephaga_	Order Coleoptera (beetles)	many insects
tiger beetles	Family _Cicindelidae_		any insect within reach
ground beetles	Family _Carabidae_		general feeders
predaceous diving beetles	Family _Dytiscidae_		" "
whirligig beetles or lucky bugs	Family _Gyrinidae_		" "

[a]Adults are predators; larval stage is parasitic.

Table III-9 (2)

BENEFICIAL INSECTS

Insect (common name)	Scientific Name		Host or Prey
lady beetles, lady birds or lady bugs	Family Coccinellidae		aphids
Australian lady beetle or vedalia	Rodolia cardinalis		cottony-cushion scale, Icerya purchasi
Australian lady beetle	Cryptolaemus montrouzieri[b]		citrus mealybug, P. citri
beetle	Catana clauseni		citrus blackfly
leaf-feeding beetles	Chrysolina gemellata Chrysolina hyperici		Klamath weed
flower flies, hover flies, syrphids	Family Syriphidae Syrphus spp. Sphaerophoria spp. Allograpta spp.	Order Diptera (true flies)	feed on aphids and other small soft-bodied insects
spiders[c] (many varieties)	Class Arachnida, Order Araneida		many insects

[b]An example of artificial ecological system is provided by the large-scale production of Cryptolaemus. In order to raise these beetles in adequate numbers, it is necessary first to raise the pest insects. Since using fruit trees or other trees is impractical, it was important to learn that mealybugs could be reared on potato sprouts. Sprouts from one ton of potatoes are capable of producing enough mealybugs to produce, in turn, 125,000 lady beetles. Potato sprouts also proved suitable for rearing black scale and therefore facilitated production of the Metaphycus helvolus.

[c]Arthropods of terrestrial habits; even large hairy species called banana spiders or tarantulas are mild-mannered. One exception, the black widow, Latrodectus mactans, has vicious habits and a poisonous bite which can be fatal.

Table III-9 (3)

BENEFICIAL INSECTS

Insect (common name)	Scientific Name		Host or Prey
PARASITES			
tachinid flies	Family Tachinidae	Order Diptera (true flies)	caterpillars, various beetles, flies, true bugs, Hymenoptera and Orthoptera
	Winthemia quadripustulata		armyworms
	Lydella stabulans grisescens		European corn borer
	Trichopoda pennipes		caterpillars, May beetles, squash bugs
	Compsilura concinnata		lives on caterpillars of gypsy moth and browntail moth; its young also develop in the larvae of 100 species of caterpillar
flesh flies	Family Sarcophagidae		parasitic on serious crop pests
grasshopper maggot	Sarcophaga kellyi		grasshoppers
Ichneumon wasps	Ichneumonidae	Order Hymenoptera (bees, wasps, ants)	larvae develop in other insects (especially caterpillars)
	Bathyplectes curculionis		larvae of alfalfa weevil, Hypera postica
	Megarhyssa lunator		wood-boring larva (the pigeon tremex, Tremex columba)
braconid wasps	Family Braconidae		
	Apanteles congregatus		tomato hornworms and other caterpillars
	Microgaster spp.		tomato hornworm; Protoparce quinquemaculata and catalpa sphinx, Ceratomia catalpae aphids
	Aphidius spp. Lysiphlebus spp. Lysiphlebus testaceipes		aphids

Table III-9 (4)

BENEFICIAL INSECTS

Insect (common name)	Scientific Name	Host or Prey
braconid wasps (cont)	*Macrocentrus ancylivorus*	oriental fruit moth, *Grapholitha molesta*
	Macrocentrus gifuensis	European corn borer, *Pyrausta nubilalis*
chalcid wasps	Family *Chalcididae*	many species
	Trichogramma minutum	150 species of several orders, codling moth, oriental fruit moth, sugarcane borer
	Aphycus helvolus	black scale
	Aphelinis mali	woolly apple aphid, *Eriosoma lanigerum*
	Coccophagus gurneyi	citrophilus mealybug, *Pseudococcus gahani*
	Pseudoaphycus utilis	mealybug, *P. nipae*
	Tetracnemus pretiosus	citrophilus mealybug
	Pteromalus puparum	imported cabbageworm, *Pieris rapae*
Proctotrupids, egg-parasite wasps and others	Family *Scelionidae*	eggs
	Eumicrosoma benefica	chinch bug eggs
digger wasps, mud-daubers, thread-waisted wasps	Family *Sphecidae*	insects, spiders
	Sphecius speciosus	cicadas
dryinid wasps	Family *Dryinidae*	leafhoppers
vespoid digger wasps	Family *Scoliidae*	white grubs and other beetle larvae
	Tiphia popilliavora	Japanese beetles
social wasps, paper-nest wasps, hornets and yellow jackets	Family *Vespidae*	
adults		nectar and carbohydrates
growing young		caterpillars and flies

Table III-9 (5)

BENEFICIAL INSECTS

Insect (common name)	Scientific Name		Host or Prey
moth borer	Cactoblastis cactorum	Order Lepidoptera (moths and butterflies)	effective control of pricklypear (weed growing wild in Australia; known as Klamath weed in U.S., Hypericum perforatum)
POLLINIZERS[d]			
native wild bees	Tetralonia spp.		alfalfa
	Mellissodes spp.		
alkali bee	Noma melanderi		"
	Megachile spp.		
bumble bees	Bombus spp.		clover
honeybees	Apis mellifera		legumes, etc.

[d]Although thousands of species of insects assist in pollination they are distributed (in order of importance) as follows: bees and wasps, flies, moths and butterflies, thrips and beetles. The value of flies, moths and butterflies as pollinators is very often offset by the damage they do as larvae.

Table III-10 (1)

VIRUS DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Virus	Causative Organism	Vector	Common Name
Potato spindle tuber	Acrogenus solani	Melanoplus spp.	grasshoppers
		Epitrix cucumeris	potato flea beetle
		Systena taenita	flea beetle
		Disonycha triangularis	leaf beetle
		Leptinotarsa decemlineata	Colorado potato beetle
		Lygus oblinaetus	tarnished plant bug
		Myzus persicae	green peach aphid
Onion yellow dwarf	Marmor cepae	Aphis gossypii	melon aphid
		Myzus persicae	green peach aphid
		Brevicoryne brassicae	cabbage aphid
		Aphis maidis	corn leaf aphid
		Other Aphidae	At least 50 species of aphids transmit this virus.
Cucumber mosaic	Marmor cucmeris	Aphis gossypii	melon aphid
		Myzus persicae	green peach aphid
		Myzus circumflexus	crescent-marked lily aphid
		Myzus solani	foxglove aphid
Bean mosaic	Marmor phaseoli	Macrosiphum pisi	pea aphid
		Myzus persicae	green peach aphid
Potato leaf roll	Corium solani	Myzus persicae	green peach aphid
		Myzus circumflexus	crescent-marked lily aphid
		Myzus solani	foxglove aphid
		Macrosiphum solanifolii	potato aphid
Sugarcane mosaic	Marmor sacchari	Aphis maidis	cornleaf aphid
		Hysteroneura setariae	rusty plum aphid
Citrus quick decline (Tristezia)	Corium viatorum	Aphis gossypii	melon aphid

Table III-10 (2)

VIRUS DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Virus	Causative Organism	Vector	Common Name
Potato yellow dwarf		Aceratagallia sanguinolenta	clover leafhopper
		Aceratagallia curvata	leafhopper
		Aceratagallia longula	leafhopper
		Aceratagallia obscura	leafhopper
Sugar-beet curly top	Ruga verrucosans	Circulifer tenellus	beet leafhopper
Pierce's disease of grapevines and alfalfa	Morsus suffodiens	Draeculacephala minerva	leafhopper
		Helochara delta	leafhopper
		Carneocephala fulgida	leafhopper
		Other Cicadellidae	At least 14 species can transmit this virus
		Aphrophora annulata	spittlebug
		Aphrophora permutata	spittlebug
		Clastoptera brunnea	spittlebug
		Philaenus leucophthalmus	meadow spittlebug
Phloem necrosis of elm	Morsus ulmi	Scaphoideus luteolus	leafhopper
Tomato spotted wilt	Lethum australiense	Thysanoptera	thrips
Latent potato virus (potato virus X)		Melanoplus differentialis	differential grasshopper
Cotton leaf curl (in Africa)	Ruga gossypi	Bemisia gossypiperda	whitefly
Streak disease of corn	Fractilinea maidis	Cicadulina mbila	leafhoppers
		C. zeae	
		C. storeyi	
Dwarf disease of rice	Fractilinea oryzae	Nephotettix apicalis	leafhoppers
		Deltocephalus dorsalis	

Table III-10 (3)

VIRUS DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Virus	Causative Organism	Vector	Common Name
peach yellows	Chlorogenus persicae	Macropsis trimaculata	plum leafhopper
false blossom (cranberry)	Chlorogenus vaccinii	Scleroracus vaccinii	leafhopper
mosaic of crucifers	Marmor cruciferarum	Myzus persicae Brevicoryne brassicae	aphids
peach X-disease	Carpophthora lacerans	Colladonus geminatus	leafhopper
peach mosaic	Marmor persicae	Eriophyes insidiosus	mite

Table III-11

BACTERIAL DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Disease	Causative Organism	Crops Affected	Insect Vector(s)
fire blight	Erwinia amylovora	orchard fruits, chiefly apples and pears	honeybee, flies, ants, wasps, aphids, leafhoppers, tarnished plant bug, bark beetles
sweet corn wilt (Stewart's disease)	Phytomonas stewarti	corn	corn flea beetle* (principal vector)
curcurbit wilt	Erwinia tracheiphila	cucumbers, cantaloupes, squashes, pumpkins	striped (Diabrotica vittata) and twelve-spotted (D. duo-decimpunctata cucumber beetles
bacterial rot	Phytomonas melophthora	apples	apple maggot, Rhagoletis pomonella
bacterial soft rot	Erwinia carotovora	potatoes, cabbage and other vegetables	maggots, Hylemya brassicae and H. cilicrura
heart rot	Erwinia carotovora	celery	two species of leaf-mining Diptera (Scaptomyza graminum and Elachiptera costata)
vascular disease	Pseudomonas saliciperda	willow (Cryptorrhynchus lapathi)	willow borer or snout beetle
wilt of Solanaceae	Phytomonas solanacearum	potatoes, tobacco, tomatoes, peppers, other related plants	potato beetles (Leptinotarsa decimlineata)
bacterial gall	Bacterium pseudotsugae	Douglas Fir	strong evidence exists that this insect is vector Cooley's Chermes (Chermes cooleyi)

*Also brassy flea beetle (Chaetocnema pulicaria), toothed flea beetle (Cdenticulata), southern corn root worm, western corn rootworm and white grubs, seed-corn maggot.

Table III-12 (1)

FUNGAL DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Disease	Causative Organism	Crops Affected	Insect Vector(s)
ergot	Claviceps purpurea	rye, barley, wheat, many grasses	pollen-eating flies, many species insects of many kinds*
wood-rot	Peniophora gigantia	conifers	Monochamus spp. beetles
Dutch elm	Ceratostomella ulmi	elm trees	elm bark beetles (principal vector is smaller European elm bark beetle, Scolytus multistriatus).
blue stain	Ceratostomella spp. C. spp., Tuberculariella ips and other fungi	pine trees	pine bark beetles (Ips pini and I. grandicollis) and other bark beetles
black stem rust	Puccinia graminis		
brown rot	Sclerotinia spp. Polyporus volvatus	peaches conifers	plum curculio;+ Conotrachelus nenuphar bark beetles
beech-bark canker	Nectria coccinea var. faginata	beech trees	beech scale
oak wilt	Ceratocystis fagacearum	oaks (all native species)	sap-feeding beetles of the family Nitiduliadae are attracted to the oak wilt mat and fungus spores adhere to their bodies; an oak bark beetle (Pseudopityophthorus spp.) an ambrosia beetle, the two-lined chestnut borer (Agrilus bilineatus) and a round-headed borer (Graphisurus fasciatus are found[▲] to be contaminated with wilt

*More than 40 species (not all of equal importance).

+Influences development of disease. Difficult to determine accurately the importance of an insect vector.

▲It is not definitely known that any of these insects spread the disease but the probability is high.

Table III-12 (2)

FUNGAL DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Disease	Causative Organism	Crops Affected	Insect Vector(s)
southern cone rust	Cronartium strobilinum	newly formed cones of slash and long-leaf pines	insects, particularly of the genus Dioryctria
perennial canker	Gloeosporium perennans	apples	woolly apple aphid, Eriosoma lanigerum
downy mildew	Phytophthora phaseoli	lima beans	bees
stigmatomycosis	Nemotospora spp., Spermophthora gossypii and Eremothecium cymbalariae	cotton, beans, citrus and other plants	plant bugs (most important are Euschistus impictiventris, Chlorochroa sayi, Thyanta custator)
yeast spot	N. phaseoli	lima beans, cowpeas	green stinkbug (Nezara hilaris)
inspissosis	N. coryli	citrus fruits	leaf-footed plant bug (Leptoglossum zonatus)
tree-cricket	Leptosphaeria coniothyrium	apples	tree crickets (Oecanthus niveus, O. angustipennis)
tomato leaf-spot	Septoria lycopersici Alternaria solani	tomatoes	flea beetles* (Epitrix cucumeris), Colorado potato beetle (Leptinotarsa decimlineata) and tomato worm (Protoparce carolina)

*The conclusion that these insects serve as vectors is based on circumstantial evidence only.

Table III-12 (3)

FUNGAL DISEASES OF PLANTS AND SOME OF THEIR INSECT VECTORS

Disease	Causative Organism	Crops Affected	Insect Vector(s)
sooty mold	Capnodium citri	citrus fruits	scale insects, aphids, larvae of white flies
potato scab	Actinomyces scabies	potatoes	potato flea beetle (Epitrix cucumeris)
blackleg	Phoma lingam	cabbage and other crucifers	cabbage maggot (Hylemyia brassicae)
red rot	Colletotrichum falcatum	sugar cane	moth borer (Diatroea saccharalis)
plum wilt	Lasiodiplodia triflorae	plum trees	peach-tree borer (Aegeria exitosa)
fusarium wilt	Fusarium vasinfectum	cotton	grasshoppers
sapwood decay	Polyporous volvatus	conifers	bark beetles

Table III - 13 (1)

INSECTICIDES

Common Name	Chemical Name	Conditions of Use
Synthetic Organic		
DDT	dichloro-diphenyl-trichloroethane	relatively safe insecticide--can be used on cattle, horses, sheep, goats, hogs, dogs, not on chickens, rodents are susceptible, occurs in milk of dairy cattle, stored in fat of beef cattle--corn and other cereal plants are tolerant, potatoes, members of cabbage family highly tolerant, some members of pea family highly sensitive as are members of pumpkin family
Methoxychlor	dimethoxy-diphenyl-trichloroethane	safe for all livestock including calves and chickens, does not tend to be stored
TDE	tetrachloro-diphenyl-ethane	like DDT in toxicity to animals, storage in fat and secretion in milk
BHC	hexachlorocyclohexane	highly toxic to germinating seeds and roots, must be used with discretion but never growing potatoes, sweet potatoes, carrots, beets, other root crops or peanuts, contaminates edible parts of plants, used early in season for controlling certain fruit insects (i.e. plum curculio)

Table III - 13 (2)

INSECTICIDES

Common Name	Chemical Name	Conditions of Use
"Lindane"	hexachlorocyclohexane (gamma isomer only)	useful against pests of livestock (young calves are highly susceptible) relatively pure--about 1/8 as much required for insect control as for BHC, less odorous but tends to be toxic to later growth
Chlordane	octachloro-hexahydromethanoindene	relatively safe, most farm animals (except young calves) can withstand 2% sprays and dips contaminant of root crops, somewhat fungicidal in large doses, generally used at 6 pounds or less per acre per crop
Aldrin (HHDN)	hexachloro-hexahydroendo-exo-dimethano-napthalene	highly toxic, handle with extreme care, effectiveness not lost in presence of alkalies or acids less toxic than Dieldrin
HETP	hexaethyl tetraphosphate	highly toxic to animals
TEPP	tetra-ethyl-pyrophosphate	chiefly against aphids and some mites--not used to control insects on man and animals
"Schradan" (OMPA)	octo-methyl-pyrophosphor-amice	against insects and mites systemic insecticide not recommended on food or fodder crops, useful on cotton and sugar beets--not on man or animals
Parathion	diethyl-nitrophenyl-thiophosphate	useful against many insects infesting various crops, oriental fruit moth no hazard through accumulating residues in soil

Table III - 13 (3)

INSECTICIDES

Common Name	Chemical Name	Conditions of Use
Toxaphene	chlorine and camphene	reasonably safe as spray for farm animals (not young calves) not as a dip, not on chickens, no hazard through accumulating residues in soil
Dieldrin	hexa-chloro-epoxy-octahydro-	not safe when used repeatedly, stored in fat of cattle, secreted in milk
Rhodanates	general name for thiocyanates	should be used with extreme care, may injure growing plant$
"Arathone"	dinitro-capryl-phenyl-crotonate	as dormant spray in apple orchards
Malathion	dimethyl-dithiophosphate of diethyl mercaptosuccinate-phenothiazine	no hazard through accumulating residues in soil
Natural Organic		
	nicotine	recommended against soft bodied insects that are minute in size and some external parasites on animals
	nicotine sulfate	effective against pests of pumpkin family
	nornicotine	
	pyrethrum	control of flies on dairy cattle

Table III - 13 (4)

INSECTICIDES

Common Name	Chemical Name	Conditions of Use
Allethrin	(synthetic product allied to compound in pyrethrum)	
	rotenone and rotenoids	control of cattle grups
	sabadilla	control of bugs on cabbage and pumpkin family crops
	hellebore	
	various oils and tars	to control scale insects and mites, used on fruit trees, used widely in California citrus area
Inorganic		
Tartar emetic	antimonyl potassium tartrate	in ant poisons and for control of thrips
White or gray arsenic	arsenic trioxide (arsenious oxide)	used as weed killer, in baits to control grasshoppers, cutworms and other insects
	calcium arsenate	used against insects affecting field crops, especially cotton; cannot be used safely on apples, peaches, beans and others
London purple	calcium arsenate-calcium arsenite (mixture)	for poisoning insects on cotton

Table III - 13 (5)

INSECTICIDES

Common Name	Chemical Name	Conditions of Use
Paris green	copper-aceto-arsenite	control of Colorado potato beetles
	acid lead arsenate	to control chewing insects on fruit and vegetables and soil treatment for control of Japanese beetles
	basic lead arsenate	safe to use on growing plants, less apt to burn plant foliage
	magnesium arsenate	against Mexican bean beetle, combatting caterpillars on tobacco
	sodium arsenite	not as an insecticide on field crops because of its corrosive action; used in poison baits for grasshoppers, crickets, roaches, ants and other insects, and in stock dips; also as weed killer
	zinc arsenate	codling moth control
	barium fluosilicate	control of flea beetles, blister beetles, Mexican bean beetle, et. al.
Cryolite	sodium fluoaluminate	against codling moth, tomato pin-worm, tomato fruitworm, lima bean pod borer, corn ear-worm, Mexican bean beetle, walnut husk fly, pepper weevil, cabbage caterpillars, beetles and flea beetles; as spray or

Table III - 13 (6)

INSECTICIDES

Common Name	Chemical Name	Conditions of Use
Cryolite (cont.)	sodium fluoride	effective against chicken and animal lice; roaches
	sodium fluosilicate	as dust and spray in the control of insects on field crops; as a poison in cutworm, mole cricket and grasshopper baits
Corrosive sublimate	mercuric chloride	fungus gnats, earthworms, cabbage maggots and onion maggots; sometimes used to control insects on man and animals
Calomel	mercurous chloride	
	selenium selenate	to kill aphids and mites on apples and grapes, not recommended on crops intended for human or animal consumption
	sulfur compounds	against potato leaf hopper, and plaid bugs, cotton flea hopper, spider mites

Table III - 13 (7)

HERBICIDES

Common Name	Chemical Name	Conditions of Use
Organic		
2,4-D	2,4-dichlorophenoxy-acetic acid, its salts (metallic and amine) and its esters	effective against broadleaf plants
2,4,5-T	2,4,5-trichlorophenoxyacetic acid	destruction of woody plants chemical thinner: apricots
2,4-D (methyl analogue)	4-chloro-2-methyl-phenoxyacetic acid	control of weeds in cereal crops
IPC	isopropyl-N-pheynlcarbamate	comparatively nontoxic to broadleaf plants but does destroy grasses
DNOC	4,6-dinitor-o-cresol	as nonselective for grasses chemical thinners: apples and prunes
DNOSBP	dinitro-o-sec-butylphenol	"
TCA or TCAA	trichloroacetic acid	"
Dalapon	2,2-dichloropropionic acid	"
PCP	pentachlorophenol	"
MH	maleic hydrazide	selective; prevents sprouting in stored potatoes, onions and other root crops used to delay blossoming and inhibit growth of fruit trees and lawn grass

Table III - 13 (8)

HERBICIDES

Common Name	Chemical Name	Conditions of Use
Organic		
NPA	N-1-naphthylphthalamic acid	pre-emergence herbicide chemical thinner: peaches
	monochloroacetic acid	used for defoliation
Inorganic		
	sodium arsenite	defoliant for potato vines
	calcium cyanamide	defoliant for cotton control of weeds in cornfields and other cereal crop fields

Herbicides are known as selective if they are relatively specific in their action and nonselective if their activity is relatively general.

Can be classified as inorganic or organic and also according to their mode of physiological activity (i.e. whether they kill plants by being growth stimulators or by their toxicant action.

Table III - 13 (9)

FUNGICIDES

Common Name	Chemical Name	Conditions of Use
Inorganic mercurials	mercuric chloride	as a 1 to 1,000 solution treating potato seed pieces, sweet potatoes, rhubarb roots for planting; seed of crucifers (plants of the mustard or cabbage family), celery, cucumber, pepper, tomato, watermelon and other vegetables
	calomel	seeds of crucifers, celery and onion
	mercuric oxide	dip treatment for sweet potatoes
Organic mercurials		
Ceresan	2 percent or 5 percent ethyl mercury chloride	used on seeds of small grains, flax, cotton, peas, hemp and sugar beets ($\frac{1}{2}$ ounce per bushel)
Ceresan M	7.7 percent ethyl mercury p-toluene sulfonanilide	useful in slurry or "quick-wet" method largely replacing Ceresans
Leytosan	7.2 percent phenyl mercury urea	applied to small grains, peas rice and sorghum at $\frac{1}{2}$ ounce to the bushel and to flax at $1\frac{1}{2}$ ounces in dust or slurry form
Agrox	6.8 percent phenyl mercury urea	
Mercuran	3.5 percent mercury as methoxy ethyl mercuric acetate	small grains at $\frac{1}{2}$ ounce per bushel; applied as dust, in concentrated solution by "quick-wet" method or more dilute solution as slurry

Table III - 13 (10)

FUNGICIDES

Common Name	Chemical Name	Conditions of Use
Organic mercurials		
Panogen	2.2 percent methyl mercury dicyan diamide	3/4 ounce per bushel for small grains; $1\frac{1}{2}$ ounces to flax and 4 ounces per 100 pounds of segregated beet seed; applied in special treater or as slurry if diluted with water
Setrete	7 percent phenyl mercury ammonium acetate	$\frac{1}{2}$ ounce per bushel
Sanoseed	7.9 percent ethanol mercury chloride	dip treatments for seed potatoes
Corona P.D.	7.5 percent mercury in mercury bromine-phenol compound	
Semesan	30 percent hydroxy mercuric chlorophenol	wet soak for bulbs, tubers and corms and as a dust for seeds of vegetables
Semesan Bel	2 percent hydroxy mercurichlorophenol 12 percent hydroxymercurinitrophenol	dip treatment for seed potatoes
Puratized N-5-E	10 percent phenyl mercury triethanol ammonium lactate	seed potatoes
L-224	experimental mercury-sinc-chromate material	seed corn
Aagrano	3.5 percent ethoxy propyl mercury bromide	effective against cereal diseases in slurry form
Semenon	2 percent isopropl methyl mercury acetate	excellent results in control of diseases of small grains and sorghum

Table III - 13 (11)

FUNGICIDES

Common Name	Chemical Name	Conditions of Use
Organic Nonmercurials*		
Spergon	90 percent chloranil (tetra-chloro- p-benzoquinone)	may be applied as a dust or slurry to seed of peas, beans, corn, sorghum, peanuts, alfalfa, clover, soybeans and other crops (control of bunt in wheat) not recommended for treating oats or barley
Arasan	50 percent thiram (tetra-methylthiuram disulfide)	used for some crops as Spergon
Arasan SFX	75 percent thiram	wettable form of Arasan
Phygon	50 percent, 2,3-dichloro-1,4-napthoquinone and 50 percent talc	effective seed treatment for corn, peanuts, rice, sorghum and most vegetables; controls bunt in wheat but not recommended for other small grains
Zerlate+	70 percent ziram (zinc di-methyl dithiocarbamate)	effective prebedding dip for controlling blackrot in sweet potatoes, also as foliage dust or spray
Fermate	70 percent berbam (ferric dimethyl dithiocarbamate)	used as Zerlate
Dow 9-B	50 percent zinc trichlorophenate	used to treat seed of cotton, corn and sorghum

* Generally less effective than the mercurials but as a rule are less injurious to seeds and less dangerous to persons using them.

\+ Similar to Zincate, Methasan Zimate and Karbam (all contain ziram as the active ingredient)

Table III - 13 (12)

FUNGICIDES

Common Name	Chemical Name	Conditions of Use
Organic Nonmercurials		
Dithane Z-78	65 percent zinc ethylene bisdithiocarbamate	as a disinfestant and chemo-therapeutic fungicide
Mycon	7.7 percent methyl arsenisulfide	effective in controlling seed-borne diseases of wheat, oats and barley that are amenable to control by fungicides
Seedox	50% 2,45-trichlorophenyl acetate	cottonseed not effective for small grains
Anticarie	40% hexachloro-benzene	control of bunt in wheat; not recommended for treating seeds of other cereals
Inorganic nonmercurials		
	copper carbonate copper sulfate	used on wheat as bunt preven-tives
	cuprous oxide (yellow or red)	serves as seed protectant for vegetable seeds (injurious to lettuce, crucifers and onions)
Vasco 4	a mixture of zinc oxide and zinc hydroxide	used on seed of crucifers, spinach and other vegetables

Fungicides may be classified as follows: disinfestants; inactivate organisms such as bunt spores borne on seed surface; disinfectants, effective against those located deeper within seed; and protectants, protect seeds from attack. Application may be dry or wet.

Fungicides should not be mixed with insecticides without knowing how they will affect each other and the seeds on which they will be used (i.e. the addition of New Improved Ceresan to DDT reduced the fungicidal action of Ceresan and the insecticidal action of DDT).

Table III-14 (1)

INFECTIOUS DISEASES OF INSECTS

Type	Causal Organism or Pathogen	Name of Disease or Description	Insects Affected
Bacterial	Bacillus larvae	American foulbrood	honey bees
	Bacillus alvei	European foulbrood	honey bees
	Bacillus para-alvei	parafoulbrood	honey bees
	Bacillus pluton Streptococcus apis	European foulbrood	larval honey bees
	Coccobacillus acridiorum (now Aerobacter aerogenes var. acridiorum)	symptoms typical of dysentery and septicemia	grasshoppers, locusts (Schistocerca)
	Bacillus popilliae	"Milky Disease"	Japanese beetle
	Staphylococcus muscae	——	house flies
Fungal*	Beauveria bassiana	muscardine	silkworm, European corn borer, codling moth
	Beauveria globulifera	closely related to above disease	many insects including the chinch bug
	Metarrhizium anisopliae	green muscardine	many insects
	Myiophagus	endoparasitic fungus	scale insects
	Aschersonia spp.	——	whiteflies on citrus (Aleyrodes citri)

*Each of the four classes of fungi (Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes, or Fungi Imperfecti) contain species capable of infecting insects.

Table III-14 (2)

INFECTIOUS DISEASES OF INSECTS

Type	Causal Organism or Pathogen	Name of Disease or Description	Insects Affected
Fungal (Cont.)	Order Entomophthorales Genera *Empusa* and *Entomophthora*		aphids, leafhoppers, flies, grasshoppers, mealybugs and various caterpillars
	Empusa muscae+		flies
	Coelomomyces	endoparasitic fungus	mosquito larvae
	Cordyceps spp.	clublike protrusion	many insects
Viral	*Borrelina* (genus)	polyhedroses	about 100 different insects
	"	jaundice	silkworm
	"	*Wipfelkrankheit*	nun moth caterpillar
	"	wilt diseases	larvae of the gypsy moth, the alfalfa caterpillar, larva of the European spruce sawfly and others
	Bergoldia (genus)	granuloses	cutworm
	Vibrio-type organisms related to cholera	——	wax moth, European corn borer
	——	sacbrood	honey bees
	——	paralysis	adult honey bees
Protozoan	*Microsporidia*	pebrine	silkworm
		nosema	honey bees
	"	microsporidian diseases	European corn borer, codling moth, imported cabbageworm
	malarial organisms *Plasmodium*	ulcers	female *Anopheles* mosquitoes

+Fatal disease.

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CHAPTER IV

ABIOTIC FACTORS

Section §1 of this chapter discusses possible effects of thermonuclear attack on the weather. Mention of the influence of weather on other biological processes has been made elsewhere (Chapter III, sections, §2, 3, 4). The influence which forests may have on climate is emphasized.

Section §2 surveys factors influencing water and soil conservation, again stressing the role of forests, mainly as ground insulators and windbreaks. The connection between forests and runoff (which supplies water for irrigation and other purposes) is pointed out. The importance of runoff in terms of irrigation is explored in Annex D.

Section §3 attempts to present a unified picture of the importance of forests, and the various mechanisms which could lead to serious forest damage as a result of thermonuclear attack. The importance of fires is stressed, since other types of damage (insects and diseases) have been discussed earlier (Chapter III, Annex C). The ecological consequences of forest fires are covered in Annex E.

§ 1. Weather

Undoubtedly the most important abiotic factor in the environment is the weather. There is little evidence, or trustworthy theory, on how a large thermonuclear attack would influence the weather. Nevertheless the subject cannot be dismissed, if for no other reason than that there are many indications that the weather would be affected (somehow) by the release of large amounts of ionizing radiation and quantities of dust, such as a thermonuclear war would entail.

Some of the "causes"* of our weather are very subtle indeed. For example there is a compound cyclic variation in the solar constant (heat produced) with one period of 40.8 months[1] which corresponds to a cyclic variation in the atmospheric potential gradient.[2] A high probability exists that the second is caused by the first or that the two have a common cause, possibly related to ionization in the upper atmosphere. A cyclic variation in ozone content of the air has been observed with a periodicity of 9 2/3 years, which can be correlated with cycles in populations of tent caterpillars in New Jersey, New Brunswick salmon, Canadian lynx, chinch bugs in Illinois and other animals.[3] It has been suggested that one causal factor affecting populations of chinch bugs may be ultraviolet radiation; the insects multiply when ultraviolet light is weak and decrease when it is strong.[4] Since ultraviolet light affects ozone production in the atmosphere, a common cause may exist. Ozone is implicated in some very tricky atmospheric chemical reactions, such as the one which produces "smog."[5] It is one example of a small cause having great effects. Pure ozone (O_3) is poisonous. A concentration of 5 parts per 10^7 causes

*Factors which show a positive correlation with weather fluctations.

"weather fleck" injury to tobacco leaves, for example.

Irving Krick, a well-known meteorologist who forecast the weather for the Normandy invasion, has gone on record[6] with predictions of drought in the Rocky Mountains and high plains states, followed by unusually cold weather for the winter of 1962-63 as a result of last year's high altitude nuclear testing and the consequent "lowering" of the Van Allen belt. Krick has stated that: "This belt changes the ozone distribution which drives the circumpolar wind system and any disturbance of its normal equilibrium results in major changes in the related barometric pressure and consequent wind distributions."[7] Krick's prediction proved to be correct, but his explanation remains in the realm of speculation.

Sunspots seem to influence the weather very much. The principal sunspot cycle of 11 years is well established. Tchijewsky [8] correlates this with epidemics of cholera, influenza and typhus, as well as other phenomena. The causal connections are not fully known but have been attributed to ionization in the atmosphere. In particular, the solar spectrum has a larger ultra-violet component during spot maxima, which in turn increases the rate of ozone production in the upper atmosphere since u-v wavelengths less than 1850 Angströms are strongly absorbed by oxygen. The ozone, in turn, strongly absorbs infra-red radiation from the earth and prevents it from being lost to space.[9] Direct correlations of sunspots with weather conditions have been investigated extensively by many people [10] and it is generally agreed that ionization in the upper atmopshere is the basic link between them.

Periods of heavy rainfall have recently been shown to correlate very well with meteor showers,* when the earth passes through the asteroid belt or the tail of a comet picking up large quantities of cosmic "dust" which drifts slowly down through the atmosphere, eventually nucleating droplets of condensed moisture in regions of supercooled water vapor and forming raindrops. The time of heaviest rainfall occurs 30 or 31 days after the meteoric "seeding."[11] The principles of artificial rainmaking are very similar, based on innoculating supercooled air masses with millions of tiny silver-iodide crystals on which the vapor starts to condense.+[12] The ability to stimulate condensation is not limited to special substances. The Wilson Cloud Chamber operates on this principle; passage of any ionized particle through a supercooled vapor leaves a chain of tiny droplets by which the path can be observed. Perhaps the principal nucleating agent for rain is common salt particles picked up from the oceans by wind.[13] Nuclear debris in the troposphere could conceivably have this effect.⊥ However the possibility has been considered and discounted, at least as regards the effects of nuclear test explosions.[15]

Large volcanic eruptions may be responsible for periods of unusually cold and wet weather, because of a similar mechanism. The huge Tomboro

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*For example, peak rainfall periods in Tokyo have been shown to correlate over a 300 year period not only with the dates, but also the intensities of the Bielids meteor shower (which vary with a 6.5 year periodicity). Observations have been made worldwide over shorter time spans. The heaviest rainfall peaks of the entire year (September 10 to 24) correlate with the Perseids meteor shower, August 10-24.

+Because the silver-iodide crystal structure is similar to that of ice at the cloud temperature.

⊥Approximately 10-100 million tons of meteoric dust enter the top of the earth's atmosphere annually, mostly micrometeorites. It is estimated that a 20MT ground burst would project 1 million tons of dust into the atmosphere.[14]

volcanic eruption 1815 (culmination of a series of major outbreaks, including St. George, Etna, Soufrière and Mayon) was followed by the "year without a summer" in 1816 (New England) during which temperatures in July averaged 7° C. below normal. The three outstanding historic volcanic events have been followed by exceptionally cold years.*

A quite different mechanism may be responsible for these observed effects. Heating or cooling of the earth due to atmospheric dust depends, first on whether the dust reflects solar radiation more or less efficiently than the longer wavelength, infra-red radiation from earth, and second on whether the two kinds of radiation are more or less likely to be scattered. Typical volcanic dust absorbs and re-radiates the longer wavelengths better than short (solar) ones, and would tend to heat the surface of the earth slightly rather than cool it, similar to the influence of ozone. However, very small volcanic dust particles (average 1.85 microns diameter--typical of the measurements made on dust from Krakatau in 1883, Mont Pelé and Santa Maria in 1902 and Katmai in 1912) also tend to reflect the short waves from the sun while only slightly scattering the longer waves from the earth. The ratio of wavelengths corresponding to maximum intensities is about 25:1 (between the sun's spectrum and the earth's) and the fine dust is approximately 30 times as effective at keeping solar radiation out as it is in keeping terrestrial radiation in. Hence, compared to normal circumstances the net result would be to cool the earth. This would hold roughly true regardless of the source of the dust or its precise characteristics. According to calculations, the net average temperature decrease (assuming the dust remained long enough in the stratosphere for the system to reach

* 1816 also coincided with the so-called "Brueckner-cycle," with an (average) 36 year period.[16] From 1700 the cold-wet periods occurred in 1740-43, 1780-83, 1815-17, 1850-53 (which followed the Irish potato famine of 1846-48), 1880-83 and 1920-24. It is interesting that of the other "large" volcanic explosions in modern times, Asama, occurred in 1883 (see Appendix III). The coincidence of some, but not all, at the Brueckner periods with excessive volcanic activity tends to obscure the cause/effect relationships.

equilibrium*) due to an amount of atmospheric dust equal to that produced by the Katmai explosion (which reduced the observed average intensity of solar radiation 20%), would be 6-7° C. Depending on whether the particles were assumed to be spherical, or flat (i.e., fragments of small glassy bubbles) from 1/750 to 1/1500 of a cubic mile of such debris would be sufficient to produce such an effect.[17]

A further point is worthy of note: the foregoing calculations assumed uniform conditions around the earth. However, the temperature is decreased roughly in proportion to the number of particles intercepting the path of the sun's rays. This is greater in high lattitudes where sunlight strikes at an oblique angle. Hence the effect in equatorial regions would be less than the average (6-7° C.) calculated, while near the poles it would be greater. Hence north-south temperature gradients would be increased, resulting in greater air circulation, higher winds, greater rainfall and snowfall, et. Taken together, the foregoing would appear to be the sort of conditions required to initiate an ice age, which, once started, some have argued, tends to be self-perpetuating.+

The sort of simplistic comparisions one can make between thermonuclear bombs and volcanoes may be highly misleading. However, for whatever it is worth, the following may give some not unreasonable orders of magnitude: On the basis of energy release, Krakatau (Appendix III) appears to have been roughly equivalent to 10^4 MT. According to rough calculations, 4 cubic

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* The length of time required to approach thermal equilibriums depends on the heat conductivity and thermal capacity of the earth's surface. The relaxation time seems likely to be rather long (perhaps decades) compared to the e-folding time of the dust layer. The latter can be calculated fairly easily from the information available (particle size, atmospheric density, etc.) using Stokes' law. The calculated result is consistent with observations, e.g. 1-2 years.

+ Snow and ice are highly efficient reflectors of solar radiation, but almost completely transparent to infra-red frequencies.[18] Hence the sun's heat is reflected and kept out, while the earth's heat is transmitted and lost. Thus further net cooling occurs.

miles of material were expelled by this explosion, and the amount which remained in the upper atmosphere* was probably at least as great as that deposited by the later, but smaller, Katmai eruption (1912) which was more closely observed and which gave rise to a measured 20% (temporary) decrease in solar radiation intensity but no long-lasting climatic effects. For further comparison, the Tomboro eruption of 1815 which was roughly 6 times larger than Krakatau in terms of cubic volume of material expelled, could have been the primary cause of the "year without a summer" in 1816. Thus nuclear ground-bursts yielding somewhere on the order of 10^4 to 10^5 MT might possibly lead to noticeably lowered temperatures, world-wide, with resulting poor harvests, etc..

The most widely discussed interaction between a possible nuclear attack and the weather, however, is in regard to secondary effects, especially the possible destruction of forests. The role of forests in water and soil conservation is discussed in the following section (§2). The influence of forested regions on the weather, if such influence exists, is through the water evaporation (transpiration) cycle.

Forests have a definite cooling effect on the earth. Temperatures near the ground average 25° F. cooler than at the canopy level on a sunny day, due to several mechanisms.

(i) Heat energy from sunlight is converted by photosynthesis into chemical energy. Relatively little sunlight reaches the forest floor, e.g. about 4% for a typical eastern deciduous climax forest (the experimental forest at Rutgers University).

(ii) Little water is lost by runoff even during wet periods. Only

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* Estimates have been hazarded of the actual amount of material put into the stratosphere by several eruptions, including Krakatau (see Appendix III), but such estimates appear to have been based on little or no solid evidence. For Krakatau published figures range from 1/4 to 1 cubic mile, but we believe them to be worthless.

1% of the rain strikes the forest floor directly. Water soaks into organic material (e.g. the bark of trees, underbrush and dead leaves, etc.) or is trapped by the roots in the soil. Instead of escaping into rivers, lakes or ground water, it is available for use in dry periods when it is evaporated (transpired) from the surfaces of the leaves. This evaporation is the principal cooling mechanism (similar to perspiration for humans). Humidity at the forest floor may be three times as high as it is above the canopy (on a dry, warm day) as a result of evaporation.

The destruction of forests as a result of thermonuclear attack would cause (1) higher ground temperatures and (2) less evaporation, over wide regions, since much of the water would run off on the surface after rains. Opinions vary, as to whether this would affect the climate. Krick,[19] Stonier[20] and others believe that it would, citing changes from wooded to desert country which have occurred in North Africa and elsewhere in historic times. On the other hand J.E. McDonald, Chief Meteorologist of the Institute of Atmospheric Physics, has stated a contrary opinion on this question, arguing that only 10% of the rain which falls on this continent originally evaporated from the land surface.[21] Furthermore in many regions transpiration is not presently an important factor, i.e. in Utah 90% of the precipitation re-evaporates before it can be removed by runoff (95% in summer, 85% in winter), regardless of vegetative cover.

In modern times there have been some attempts to carry out controlled experiments to settle the question (which considerably ante-dates the CD controversy). One such experiment (in 1875) was carried out in central

India in connection with a reforestation project, though the results unluckily turned out to be almost useless as a result of coincidental climatic changes. A careful series of observations in Germany (1937) indicated that about 6% of the rainfall on the Letzlinger heath is traceable to the effects of reforestation.[22] A less careful set of measurements was made in the Congo (1934) which, however, gave more dramatic results: namely, that in the virgin forest, rainfall was 30% higher, humidity averaged 15% higher and temperature 1.5% lower than in surrounding unforested areas.[23]

The fundamental question at issue seems to be whether a forest-less area of wide extent would produce the sort of updrafts which lift moisture-laden air into regions of low pressure where adiabatic cooling (and condensation) will take place.[24] (Mountain chains rising from sea-coasts illustrate the process.) There is no real agreement on this point at present, although the weight of the evidence seems to point toward a modest, but real, drop in total rainfall coupled with slightly higher temperatures.

§2. Water and Soil Conservation

Forests play a major role in water and soil conservation, which would be disrupted if widespread destruction occurred. The question which arises (and on which a controversy exists) is what the major effect would be.

It was pointed out in in section § 1 that loss of forests would certainly result in (1) higher soil temperatures and (2) less evaporation. A corollary of point (2) is that water available for runoff would be correspondingly greater. In fact in Utah, Texas, New Mexico and California, it is standard practice to poison, uproot or burn stands of native chaparral, and other woody brush, to facilitate the growth of range grasses. It is

found by experience that the result is usually to increase the amount of ground water available (the water-table rises), presumably because the shallow-rooted grasses prevent surface evaporation more effectively than brush but do not draw water up from deep below the surface in dry periods. The well-known salt cedar, a brushy tree which grows along stream beds and irrigation canals, is a particular offender.

It may be important to distinguish between the lower slopes and foothills, and the upper slopes of the mountains, where grass does not grow well. In the Western U.S. 85% of the water used for irrigation comes from runoff from the higher slopes where pine, spruce and aspen are found.[25] These slopes seem to be inherently more resistant to erosion; only 10% of the silt accumulated in reservoirs comes from higher elevations. On the lower foothills (piñion-juniper) the principal cause of erosion seems to be overgrazing by livestock which reduces the ground covering of the grasses.

Without taking into account secondary effects such as fires and early melting of snowpack, the situation as seen by W. Criddle, Utah State Water Engineer, is as follows:[26]

(i) Assuming pine-spruce-aspen forests at high elevations were killed by radiation (see Chapter I, section §3 for data on radio-sensitivity of conifers) total runoff would increase but the rate would not change significantly due to protection of the ground by vegetative litter (pine needles, etc.).

(ii) Assuming piñon-juniper on lower slopes were killed but did not burn, total runoff would again increase and the ground water level would also be improved.

Of course fire is a serious possibility, especially if large areas of forests have been killed by radiation or beetle outbreaks facilitated by radiation injuries. In densely forested areas such fires could be extremely hot, destroying much of the organic ground litter and humus. In less densely wooded regions fires would probably be more similar to the brush fires which occur regularly after draughts. Criddle estimated that runoff would again be increased in both cases, and that serious erosion might also occur on the lower (piñon-juniper) slopes.

Fires over semi-arid grassland and range would almost certainly be more beneficial than harmful (biologically speaking). The Indians of the Southwest formerly burned the prairie regularly, and fire is increasingly being used again as a deliberate method of controlling the ecological succession of the range. Fire favors grasses against competing woody plants such as mesquite brush. Indeed, during the long period during which grass fires have been more or less rigorously suppressed, mesquite has spread over 75,000,000 acres of former grassland. This land would be partially returned to grass in the event of widespread fires, since perennial grasses lose only a year's growth in a fire and produce plenty of seed in the first or second year following, while woody shrubs require several years after germination to produce seed. Grass is economically valuable as forage, whereas relatively unpalatable shrubs are virtually useless, besides being more wasteful of ground water.[27]

Other ecologists have expressed fears that the situation would be worse than has been portrayed here, possibly due to the effects of wind. John Wolfe of the AEC, in a statement at the Congressional Hearings on Biological Consequences of Nuclear War remarked:[28]

> Removal of turf by fire and erosion on plains and prairies would result in uncheckable erosion by winds with subsequent expansion of present dust bowls and creation of new ones of wide extent. Emergency overgrazing and over-cultivation, if there were those to work, would wreak further havoc.

In an eastern deciduous forest, wind velocity on the forest floor averages only 3% of the velocity above the canopy. In western conifer forests the figures are somewhat higher. But with the trees dead it is conceivable that vegetative litter protecting the soil surface would eventually be removed in many areas by the combination of wind, fire and runoff from subsequent rainfall, which causes mechanical compaction of the soil and reduces its ability to absorb and retain water.[29] The eroding capabilities of wind were well illustrated by the dust bowl of the 1930's which resulted from loss of ground cover due to overcultivation and low rainfall. On the other hand, even a modest reduction of wind velocities near the soil surface has a marked effect. A study in Schleswig-Holstein in north Germany showed that hedgerows, between the fields, by reducing air circulation, reduced evaporation from the soil surface to an extent equivalent to a 33% increase in annual rainfall.[30] Physical barriers also inhibit wind erosion by trapping the heavier particles and preventing the abrasive action which would otherwise occur as the particles accelerate. From 60% to 95% of the moving soil mass never rises more than one foot above the surface. Most of the material moves by a process known as "saltation" which consists of short sliding or rolling movements along the surface, followed by bounces or jumps through the air. The heaviest grains "creep" as a result of impacts from particles in saltation. The ratios of distance travelled to maximum rise of these forward jumps ranges from 7 to 10, with the larger ratio for jumps over 6" in height. Thus the width and depth of furrows are important. The over-all

rate of movement of eroding material increases to a maximum (determined by drag forces) with distance downwind from a barrier. For completely erodable soils (e.g. fine dune sand) maximum velocity is reached in 10 yards, but for most cultivated soils maximum would not be reached for 500 yards or more. Hence the efficacy of even rather widely spaced barriers such as hedges.[31]

Past experience supplies some evidence for each point of view, but the net result is inconclusive. Careful long-term experiments at the Coweeta Hydrologic Laboratory, Asheville, North Carolina, have demonstrated the consequences of heavy grazing, logging, and mountain-farming on steep slopes in terms of erosion.[32] Overgrazing produced by far the worst effects, but serious erosion did not occur for several years. In the first few years surface litter prevented rapid runoff; not until channel blockages of organic detritus had been washed away did erosion become rapid. However it should be noted that cultivation also produced serious degradation. In seven years corn production dropped from 23 bushels/acre to only 2 bushels per acre, despite applications of commercial fertilizer (145 lbs/acre) from the fifth year on. Moreover maximum flood peak runoff was 8 times higher on the cultivated slopes than it had been prior to cultivation.

One further factor which could possibly* contribute to serious flooding as a result of nuclear attack is rapid melting of snowpack, resulting from deposition of fallout on the surface of the snow, and lack of shade due to defoliation of trees. Coal dust is sometimes

*It must be recalled that the local warming may be counteracted by an over-all cooling. See the discussion of dust in §1.

spread over snow-covered fields in Scandinavia to hasten spring melting. Dust deposited by windstorms can have the same effect, due to the enhanced heat absorption by the dark-colored material. (Temperature differences of 20-25° between dark and light surfaces are observed.) Snowdrifts sprinkled with dust or soot become pockmarked and honeycombed as some parts melt faster than others. The reflectivity of the surface decreases still further, as the selective melting proceeds. The albedo (reflectivity) of old or wet snow may be as low as 43% of the value for new powdery snow.[33] The net result can be a compression of the period of thaw from a month or so, to a few days. Stonier[34] has calculated that a 20 MT ground burst would produce sufficient fallout (assuming 10% of the crater material were involved) to cover an area of 3600 square miles to a depth of 1 millimeter. This is probably too large a number in view of the fact that deposition will be far from uniform, but it suggests the order of magnitude which might be involved.

The consequences of a speed-up of melting over large areas could be more important than may be commonly supposed. It is known that

> ...the river channel is large enough to accommodate all the water coming from the drainage area only in the relatively frequent event. The flat area bordering most channels--the flood plain--must flood to some extent every other year. <u>To overflow the flood plain is an inherent characteristic of a river</u>.[35]*

It is also known that sediment in river or channel bottoms does not move at all until a finite threshold velocity is reached. Moreover even

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*Italics added. The statement quoted is based both on theory and observation. Frequency of overbank flooding is very nearly constant for a wide variety of rivers.

beyond the threshold, the amount of material set in motion is proportional to the shear forces due to the strength of the current. In other words, for a given current velocity a dynamic equilibrium exists with respect to the amount of moving sediment--the stream cannot carry more and more indefinitely or it would become a river of mud. A corollary of these facts, however, is that "scouring" action only occurs in floods and is a sharply increasing function of the magnitude of the flood. This in turn depends primarily on the rate of runoff, not so much on the total amount. Hence the significance of the Chart (Figure IV-1) taken from reference (32).

Paradoxically, the increased runoff due to destruction of trees could result in sharp increases in water available for irrigation and/or power, in several western states. It happens that reservoirs for many irrigation systems were built with substantial excess capacities. Statistics are included in Annex D.

FIGURE IV-132

Distribution of storm runoff for an average of typical summer storms under forest cover, mountain farming, and after 2 years of rehabilitation.

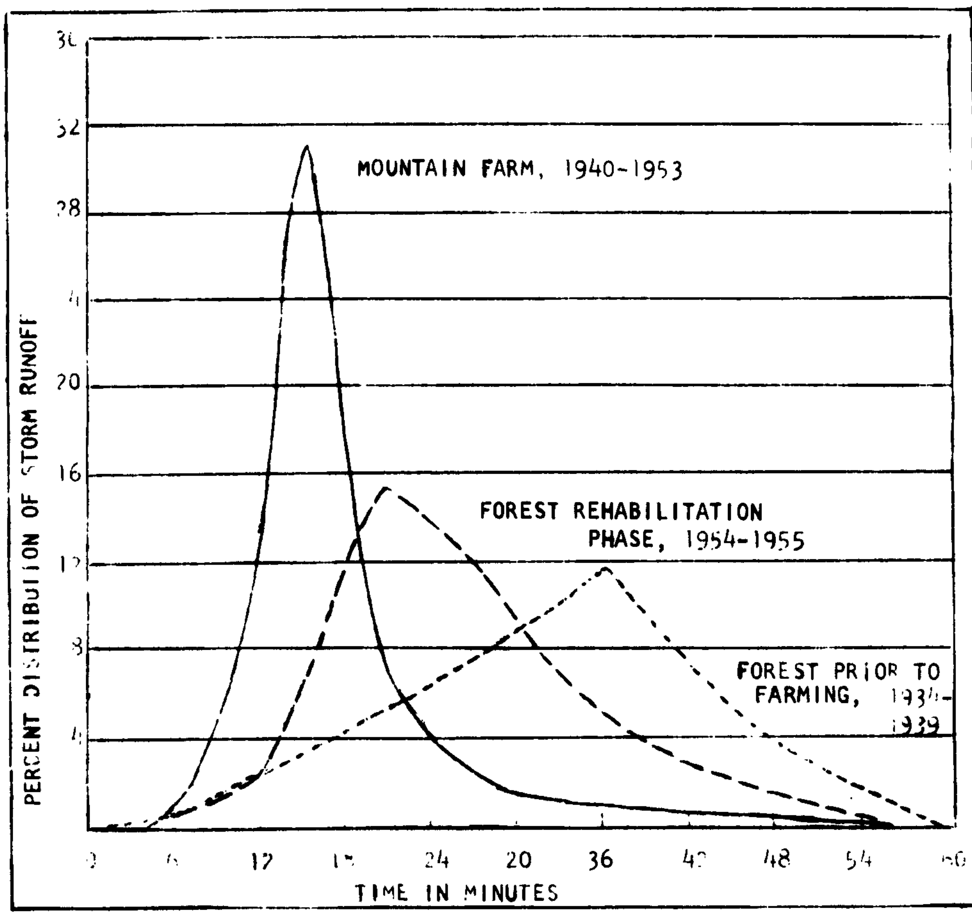
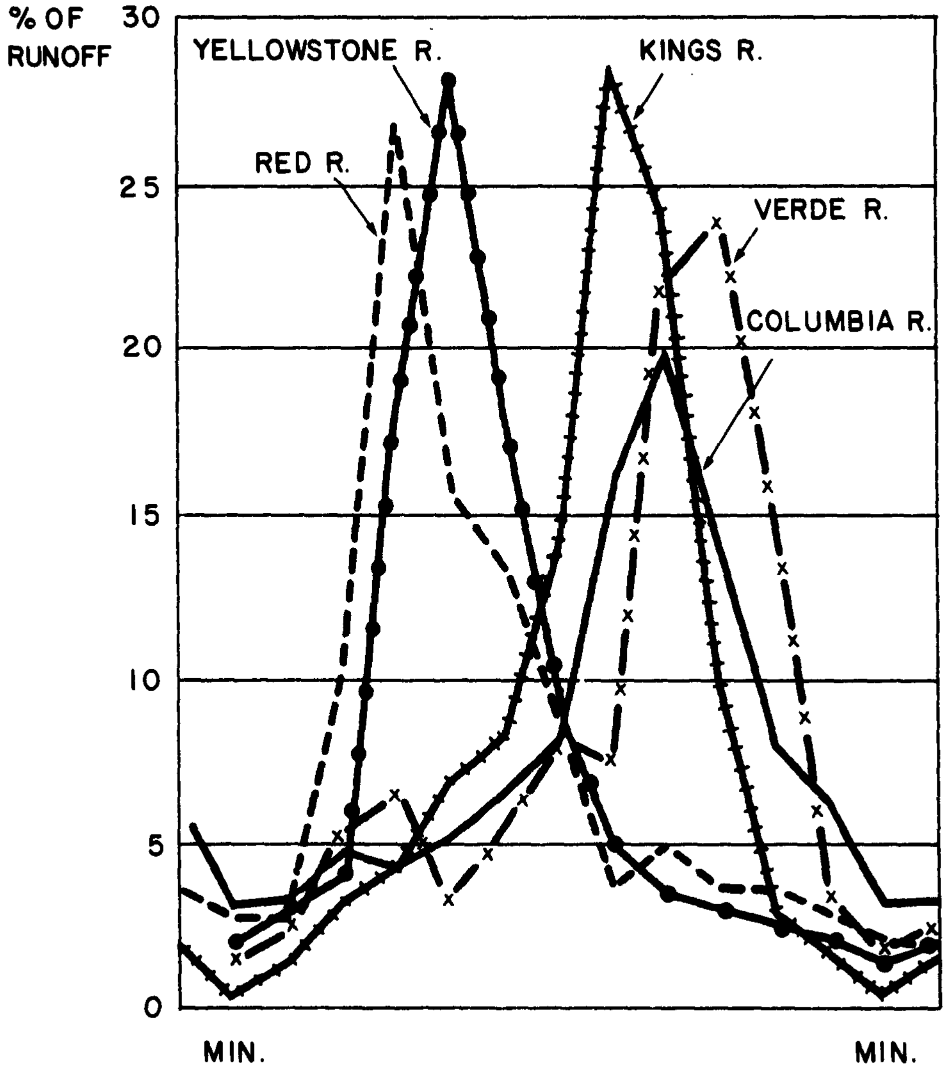


Fig. IV-2 shows the average annual runoff from five snow-fed rivers in the U.S. In view of the foregoing discussion of flooding, the channel capacity of the river will be found to be roughly at (or slightly below) the highest point of each curve. The annual curves are plotted in each case from minimum to minimum disregarding the actual months of the year when the minima and maxima occur. Allowing for changes of time scale, a generic resemblance can be seen between these curves and the curves for runoff from a mountainside (Fig. IV-1) under "normal" conditions. In both graphs the per cent. of runoff is plotted against time. Speaking still in very general terms, it would be reasonable to expect the curves, under conditions of accelerated melting, to resemble one of the other, more peaked, curves of Fig. IV-1. Should this occur, it is obvious that channel capacity would be very greatly exceeded at peak runoff, resulting in calamitous floods, and that little water would flow at other times.

FIG. IV-2
(See Ref. 36)

ANNUAL RUNOFF FROM FIVE SNOWFED WESTERN RIVERS



PEAK MONTHS
MAY-JUNE IN NORTH,
FEB.-MARCH IN SOUTH.

§3. Forests

The importance of forests with relation to weather and water/soil conservation questions was discussed in the two previous sections (§1 and §2) of this chapter. Forests as a source of useful crops and their connection with pests was mentioned in Chapters II and III respectively. From Table II-1 it can be seen that forest and forest/grass lands cover one third of the total land in the United States. Tables IV-4 and IV-5 and Map IV-1 give a statistical and geographical breakdown of forest distribution and type.

The importance of forests in the ecosystem arises from the following multiple roles:

(i) Forests as sources of wood (structural material, fuel, etc.) paper, etc.

(ii) Forests as climatic (temperature-humidity) factors

(iii) Forests as watershed cover

(iv) Forests as wildlife refugia.

The first and last points have not been dealt with at length. It is perhaps unnecessary to return to them now, inasmuch as destruction of forests (e.g. as watershed cover) also destroys their other useful functions. (One reservation should be noted: dead, but unburned trees can be harvested for wood within limits; even burned trees can be salvaged.)

Our main concern here is to evaluate the survival possibilities of forests in a postattack environment. Destruction may be due to

1. Blast
2. Radiation (prompt or delayed)

TABLE IV-1 [37]

FOREST TYPES IN U.S.

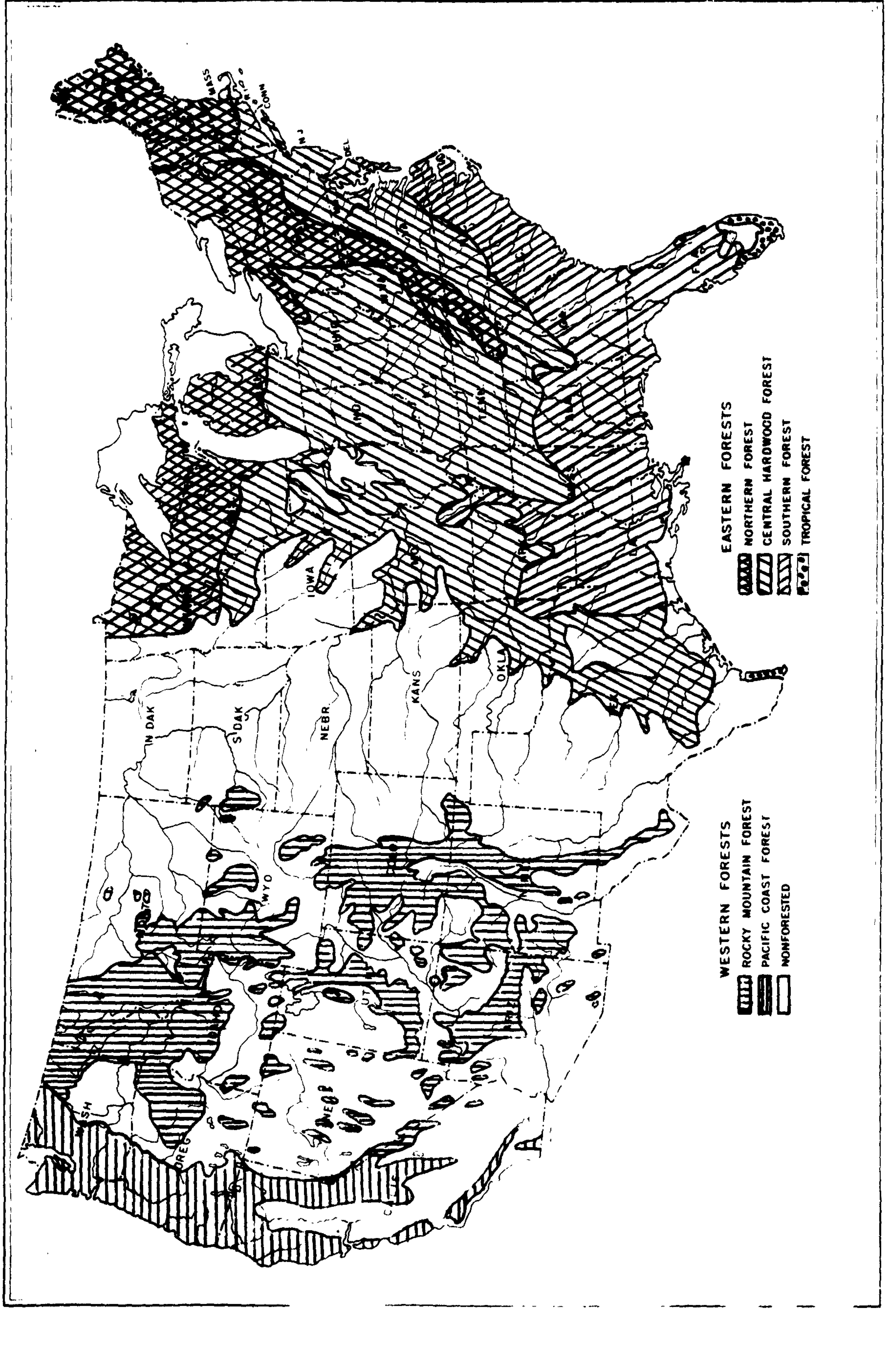
(Percentages based upon commercial forests.)

Forest Type	Per Cent
Oak - Hickory	23
Loblolly - Shortleaf Pine	12
Oak - Gum - Cypress	8
Ponderosa Pine	8
Maple - Beech - Birch	7
Douglas Fir	6
Other Eastern Softwoods	12
Other Western Softwoods	10
Other Eastern Hardwoods	13
Other Western Hardwoods	1
	100

TABLE IV-2 [37]

FOREST DISTRIBUTION IN U.S.

		Per Cent of Nation's Land	Per Cent of Total Land Covered with Forests	Per Cent of National Forest
NORTH:	New England	2.1	77	5
	Middle Atlantic	4.5	51	7
	Lake States	6.3	45	8
	North Central	9.7	23	6
	Plains	19.3	9	5
SOUTH:	South Atlantic	3.9	62	7
	South East	8.4	59	15
	West Gulf	4.7	58	8
WEST:	Pacific Northwest	5.4	52	8
	California	5.2	43	6
	Northern Rocky Mtns.	11.2	25	8
	Southern Rocky Mtns.	17.5	26	14
	Coastal Alaska	1.8	45	3
		100.0		100



FOREST REGIONS OF THE UNITED STATES

3. a. Fires ignited by thermal pulse

   b. Fires started spontaneously at later times

4. Disease or insect plagues

Blast. This would clearly be a relatively minor cause of destruction in most plausible attack patterns. Shock waves from a nuclear explosion would flatten trees over a considerable range but insufficient data exists to determine the area accurately.[38] However the range over which fires would be ignited is probably greater, for a large-yield weapon, except perhaps under special weather conditions.

Radiation. Prompt radiation would not be expected to injure trees not killed or severely damaged by blast effects. Fallout is the main hazard at more remote distances. Susceptibility of some species of trees to γ-radiation is given in Table I-2 (Chapter I § 3). It has already been pointed out (Chapter III § 3) that a synergistic effect due to combined environmental pressures, such as radiation-damage plus insect pests or disease may be the most severe consequence.

Fire due to prompt ignition. The number of calories/cm^2 required to ignite fires depends on the length of time over which the heat pulse is delivered, which depends on the yield. For large-yield weapons (20 MT) from 9-18 calories/cm^2 will ignite materials ranging in combustibility from dry rotted wood (punk) to conifer needles. Assuming the same weapon, thermal pulses of this order can be delivered at slant-range distances of the order of 25-30 miles.[39]

Fires started simultaneously over large areas by this mechanism

would tend to burn hotter and more completely than conventional forest fires. In fact one would expect a "fire-storm" to occur. Serious question exists as to whether such fires would spread widely or not. Arguing the negative, Hill[40] points out that World War II fire-storms in Hiroshima, Hamburg and Tokyo did not spread. In fact in no case was 100% of the "seeded" (with incendiaries) area actually involved in the fire-storm. This is explained by the violent updrafts, which cause strong, radially-converging winds which tend to confine the conflagration to its point of origin. On the other hand, to the extent that fires ignited by nuclear weapons can be compared with ordinary forest fires, it must be noted that weather conditions are the principal determinant. So-called "catastrophic" fires occur relatively infrequently (averaging 9 years apart) and only follow exceptional weather conditions. Hill estimates that a 2000 MT attack would result in fires burning an area comparable to that destroyed by forest fires of natural origin in 1930 (a very bad year, admittedly).

Wolfe[41] and Stonier[42] anticipate rather more serious spreading of fires, due to breakdown in firefighting capability and possibly unforeseeable effects due to higher temperatures of forest firestorms. One factor which might support the latter view, and has not been discussed to date, is the fact that deliberate suppression of fires in many forested areas of the West has created conditions where fires, once started and unchecked by human intervention, could be far more serious than they would have been under "natural" conditions of repeated small fires. For example, the ponderosa pine forests of the Southwest have changed character in the last 75 years, due to assiduous fire prevention. Once they were open and park-like in character, and

consequently mature trees normally survived the small fires which regularly cleared out undergrowth and debris. Foresters are said to have referred to these stands as "asbestos forests." Today they are cluttered with enough accumulated fuel to support far hotter and more destructive fires. On the other hand where fire is already widely used as a tool for range management, particularly in Southern longleaf forests, there would be correspondingly less danger of holocaust.[43]

It is perhaps noteworthy that human intervention is generally agreed to be effective only against small or incipient fires. When "catastrophic" fires do occur firefighters are helpless (and often do well to escape alive). Such fires can be extinguished only by natural barriers or weather changes. It would seem, therefore, that a breakdown in fire fighting or fire prevention capability is unlikely to make any difference in the worst cases being considered.

Later Fires. Here the analogy with conventional forest fires is certainly sounder. The source of danger would be large areas of dead trees--killed, perhaps, by combinations of environmental pressure (radiation, insects, disease). Ignition would occur as a result of lightning strikes, which account for 80% of forest fires at present.

Dry, dead forests are certainly more combustible than live ones, but probably only slightly so.* Climatic factors are certainly more important. The greatest danger would be of a combination of appropriate climatic conditions (long drought, low humidity, high winds) and dead forests. More

*In terms of ignition probability.

important, perhaps, the burning of dead trees would also produce hotter fires than the burning of live ones. Where the trunks themselves burn, hot smouldering piles of ashes would be left to heat the soil and destroy much of the organic matter in it.

Ecological consequences of forest fires are surveyed in Annex E.

Disease or Insect Plagues. The potential seriousness of such plagues cannot be overemphasized. Trees are particularly susceptible--the Englemann spruce beetle case alluded to before (Appendix II) is one example. A different kind of plague was the chestnut blight which killed virtually 100% of the chestnut trees in North America (where many eastern forests were over 60% chestnuts). The Dutch Elm disease is rapidly eliminating another species. Oaks may be in danger now.

As has been pointed out several times, outbreaks of insects or diseases would be a possible secondary effect of a nuclear attack, possibly intensified as a result of trees being weakened by radiation (or fires). Insect pests, diseases and carriers have been listed in Annex C of Chapter III in conjunction with the discussion of insects.

ANNEX D
(to Chapter IV, § 2)

Availability of Reservoir Capacity in Western Desert Irrigation Districts

The following tables were compiled for this study from original individual reservoir records of the Water Resources Division, Geological Survey, Department of the Interior, that lists monthly measurements in acre-feet stored in each reservoir.

From these summary tables it may be noted that if an increased, earlier-than normal April runoff had taken place in New Mexico, in an average year (of the 1938-1947 period), much of this water would have been retained for summer irrigation use, since in April the six largest reservoirs averaged only 47% full.

Likewise, the twelve largest reservoirs in Colorado (in the 1938-1947 period) averaged only 46% full in the critical month of April, while in Utah (during the ten-year period 1951-1961) the fourteen largest reservoirs held an average of 57% of their maximum capacities in the same month.

TABLE IV- 3

SIX LARGEST IRRIGATION RESERVOIRS IN NEW MEXICO
WITH COMPLETELY RECORDED ACRE-FEET (THOUSANDS)
OF STORED WATER, 1938-1947

Reservoirs	Capacity of Reservoir	Average in April*	Aggregate Monthly Average Over 10 Years
Alamagordo	122.1	59.3	59.4
Elephant Butte	2,273.7	1,133.6	1,169.1
Caballe	365.0	178.8	123.8
El Vado	226.0	61.9	89.5
McMillan and Avalon	44.5	20.8	15.9
Conchas (1939-1948)	600.0	256.0	263.9
Totals	3,631.3	1,710.4	1,721.6

* Peak of thaw period (high runoff)

TABLE IV- 4

FOURTEEN LARGEST IRRIGATION RESERVOIRS IN UTAH
WITH COMPLETELY RECORDED ACRE-FEET (THOUSANDS)
STORED, 1951-1960

Reservoir	Highest Single Level Over 10 Years	Average in April *	Aggregate Monthly Average For 10 Years
Bear Lake	1.3	1.0	0.9
Deer Creek	153.2	105.3	104.7
Echo	74.2	51.1	34.5
East Canyon	28.9	21.8	15.3
Hyrum	15.8	14.4	9.5
Moon Lake	36.5	16.6	12.6
Otter Creek	54.8	33.9	20.8
Pine View	84.6	31.6	20.0
Piute	74.0	39.6	24.5
Rockport	58.7	14.9	23.0
Rockyford	21.0	13.1	8.6
Scofield	76.5	29.5	27.2
Strawberry	278.4	175.6	165.9
Servier Bridge	211.0	115.5	71.9
TOTALS	1,168.9	663.9	539.4

* Peak of thaw period (high runoff).

TABLE IV-5

TWELVE LARGEST IRRIGATION RESERVOIRS IN COLORADO WITH COMPLETELY RECORDED ACRE-FEET (THOUSANDS) OF STORED WATER FOR 1938-1947).

Reservoirs	Capacity of Reservoir	Average in April*	Aggregate Monthly Average Over 10 Years
Riverside	57.5	42.4	31.9
Twin Lakes	54.4	22.6	28.5
Adobe Creek	61.6	23.1	27.1
Point of Rocks	70.0	56.4	37.4
Chessman	79.0	60.3	63.0
Eleven Mile	81.9	73.6	75.4
Rio Grande	103.2	16.0	16.9
Taylor Park	106.2	61.8	70.2
Green Mountain	146.9	57.4	95.0
Great Plains	150.0	44.2	38.8
Rio Grande	51.1	16.4	14.6
Cucharas	40.0	5.8	7.2
Totals	1,001.8	460.0	506.0

*Peak of thaw period (high runoff)

ANNEX E

(to Chapter IV, Section 3)

ECOLOGICAL AFTEREFFECTS OF FOREST FIRES

Effects on Soil

As a general rule erosion and runoff are more severe on burned tracts. One set of figures for Oklahoma showed increases by multiples of 12 to 31;[44] another set for the pine forests of the Sierras showed runoff up by a factor of from 31 to 463 and erosion up by factors of 2 to 239.[45] Results vary with topography, soil and type of vegetation. In some instances burning does not cause much damage, or may even be adjudged beneficial, particularly when one or more of the following is true:

(i) land is flat or gently rolling,

(ii) soil is porous (e.g. sandy),

(iii) the area is quickly reinvaded by the prefire species or a more desirable one.

The New Jersey or Southeastern pine barrens as well as some brushy wooded grazing areas in California suffer relatively slightly. In fact fire is sometimes deliberately prescribed to reduce duff and litter, prepare the seedbed, and reduce competition from subordinate vegetable species.[46]

In most cases moisture retention is definitely reduced in the upper layers of the soil because direct rainfall uninterrupted by foliage can cause compaction. Burrowing species of soil fauna may be reduced in number. Reduction of humus (organic detritus) content can be correlated with lower water-holding capacity, sometimes for as long as 50 years after a fire. However at the deeper levels the change, if any, tends

to be in the reverse direction, e.g. water tables often rise. Where the water table is already high swampy conditions may be created, as has happened in Alaska.

The texture of the soil may be affected by fires. In some cases burned soil (especially clay) becomes harder and less permeable to water, due to partial baking ("colloidal aggregation"). Sometimes reduction of porosity is also ascribed to destruction of insects, earthworms, and micro-organisms which normally channel the soil. Temperatures measured in various fires are given in Table IV-6.

The dramatic differences between the measurements in different cases are probably mainly due to a difference in soil water content and in the length of the burning time, which depends on the amount and type of fuel available. A point to remember is that in most fires there is insufficient time for a steady-state temperature gradient to be reached. Therefore a high temperature "pulse" is created as the fire burns at the surface which starts (very slowly) to penetrate the soil. If the fire passes within a relatively short time, before the heat penetrates far, the surface cools down quickly by radiation. However if a thick insulating layer of ashes is formed on the ground, the heat may be trapped. The greater conductivity of porous sandy soils is probably due to convection or "percolation" of hot air or water.

Chemical changes due to heating do not fit any simple pattern. In some cases soluble minerals are released from ashes of organic materials, thus temporarily increasing fertility. In other cases growth-inhibiting compounds are apparently formed. Fairly general agreement exists to the effect that some heating (e.g. less than 200° F) tends to be beneficial,

TABLE IV-6[47]

Soil Temperatures in Various Forest Fires*

(in degrees Fahrenheit)

1. Heavy forest fuels (Douglas fir, cedar, hemlock) in Western U.S.	1841 608	above the surface 1 inch in soil
2. Heavy forest fuels (same as above)	850 120 60 75	above the surface under 3/4 inch of duff under 1½ inches of duff 1 inch in soil--no duff cover
3. Long leaf pine (Southern U.S.)	150-175	under 1/4 inch for only 2-4 minutes, negligible rise in temperature under 1 inch
4. Spruce and pine slash (Russia)	500	1/4 inch in sandy soil (Heat penetrated deeper in sandy soil than in heavy soils, in this fire.)
5. Spruce and pine slash (Australia)	178-415 150	1/4 inch in sandy soil 1 inch in sandy soil
6. Mixed chaparral of blue oak, dwarf interior live oak, wedgeleaf ceanothus, with scattered herbs (Calif.)	840 410 235	½ inch in duff ½ inch in soil 1½ inches in soil
7. Common manzanita, scattered grasses and weeds (Calif.)	960 215	½ inch in litter 1½ inches in soil
8. Light fuels, burning two hours (Sandy soils in a eucalyptus forest in Australia)	480 235 145 95 59 54	at surface 1 inch in soil 3 inches in soil 6 inches in soil 9 inches in soil 12 inches in soil

*Variations and discrepancies in temperature figures in spite of similar vegetation and soil are due to different methods of measuring, seasons, weather conditions, type and quantity of dead plant material on the ground. These conditions were not specified in the citations mentioned above.

at least to grasses and cereal grains. Certain pathogenic organisms (fungal spores, bacteria) are more easily destroyed by heat than the protected plant seeds. Some plant seeds, such as Rhus spp, germinate 17 to 60 times as well after heating.[48] Other pyrophilic species are Cheonathus, Rhamnus californica, Abies magnifica, Pinus ponderosa, Pseudotsuga taxfolia, and Avena.

Soil temperatures stay higher after burning because of blackening and charring which greatly increases heat absorbtion. At the surface temperatures run about 20° F. higher on a sunny day, though at night they tend to be cooler due to correspondingly more efficient radiation. At a depth of one inch, under burned grasslands, minimum (annual) temperatures average 2° higher and maxima average 12° higher. At three inches depth (where the year-round temperature is more nearly uniform) both minimum and maximum average 4-5 degrees higher. Temperature differences such as these may affect vegetation quite seriously, i.e. seedlings and N-forming bacteria may be killed, spring germination comes earlier, etc.

Spruce and alder seem to be particularly inhibited by the presence of ash, but pine and larch are also slowed. In other cases pines, grasses and other species appear to be stimulated, perhaps due to lack of competition from other species. Contradictory results can be explained by the fact that depleted soils may in some cases be temporarily rejuvenated by the return of minerals from ash to the ground. Unless these minerals are quickly reincorporated into plant tissue they may be leached away. Heathlands in England, after burning, were found to lose 70% of the soluble mineral salts in the top two inches and 86% below that, in only two months.[49]

Loss of humus is a frequent result of fires. In old pine or spruce forests there may be a very thick layer of needles, cones, etc. on the ground. Fires have been known to burn as much as two feet of this organic layer. Various measurements are found in Table IV-7.

TABLE IV-7[50]

Fire (regions, type)	Reduction of Humus*
1. western Oregon, Washington (Douglas-fir, hemlock, spruce)	75% loss in top ½ inch; still 50% below normal after 2 years
2. sagebrush and grasslands	"significant" loss in top ½ inch, but temporary
3. " "	33% loss in top 3 inches, negligible loss below
4. grass (annual burning 42 years)	2088 lbs/acre
5. Minnesota (spruce, fir, aspen, birch)	7 to 26 tons per acre, top layer
6. western white pine forests	"takes 50 years or more to replace"
7. Adirondacks (spruce, fir, hardwood)	average depth of 2 inches burned
8. Alaska (spruce, hemlock)	burning to mineral soil level occurred on 30% to 40% of total burned surface
9. Florida--annual burning (open-longleaf, slashpine)	"serious" down to 4-5 inches

*No consistent parameters for recording losses are available.

Effects on Living Organisms

Often mosses and lichens are destroyed by fires and take a long time to recover, especially in northern forests (Canada, Minnesota, et. al.). On the other hand in the New Jersey pine barrens destruction of trees stimulated both mosses and lichens, especially the latter. In some cases mosses and lichens are actually characteristic of post-fire successions.

Many plant diseases are checked by fires (which destroy insect vectors or spores of fungi but do not actually kill the trees). For example, brown needle spot Septoria acicola in long leaf pine is drastically reduced during the furst and second years following a fire. Further examples may be cited. On the other hand post-fire successions are very favorable breeding grounds to certain diseases. Fire scars on aspen, jack, red and white pine allow entry to heart rot, Fomes ignarius. Wood boring insects which destroy the habitats of birds often increase after fires. Fire damaged stands may serve as breeding grounds for insects or fungi. Also disease resistance of trees seems to be adversely affected by heating soil above 250-300° F.

Bacteria are influenced by the altered acidity (pH) of soil after fires, due to the (temporary) release of alkalis from ashes. In most cases such effects seem to be very short lived (of the order of one week) but in the Douglas-fir region slash burning with the subsequent release of calcium favors the growth of nitrogen-fixing bacteria Azotobacter and Clostridium.

In the top two inches of burned soil the population of invertebrates (insects and worms) may drop to as little as 10% of prefire numbers depending on temperature. Earthworms are comparatively more susceptible than other species.[51]

Vertebrates react variously. Deer prefer subclimax (e.g. post-fire) vegetation, as do grouse. Other species such as Caribou (in Canada) disappear following a fire. Small fires destroy relatively few individuals directly, due to burrowing habits or mobility. Some birds, e.g. wrens, quail, bluebirds, actually follow fires, nesting in fresh burns. Fires which destroy popular nesting places such as marshes, and especially if eggs and young are trapped, may lead to increases in insect activity. Squirrels often disappear from burned areas for ten years, as do beavers and other fur-bearing species. Mice, such as Microtus, require at least one year's mulch for runways. Controlled grass fires in long leaf pine woods help cut the rat population. Fish are often killed by the wash of ash into streams and ponds.

Plant species react very differently. Species by species analysis would be required. Definite patterns of post-fire succession exist, but depend on the climate, soil, surrounding vegetation, etc. Usually, herbs, grasses, and shrubs invade the burned area. Seeds may be windborne or long-dormant already underground (perhaps stimulated to germinate by the heat). Many brushy species sprout vigorously after fires from surviving roots. Seeds of other species are brought into the site by animals browsing on the plants which grow at first after the fire. Access of sunlight and removal of forest litter favors seedling growth for conifers as compared to deciduous species. The former are inherently faster growing but cannot penetrate litter due to shallow root systems and increased need for water. Hence deciduous species seldom follow burning.

Jack pine (Pinus banksiana) follows fires in the north, but is only moderately fire-resistant itself; seeds in cones remain viable for many years, cones being opened by heat. Jack pine prefers sandy soil.

Paper birch and white pine (Pinus strobus) often follow fires in northern Minnesota. Paper birch is easily killed by fire, while white pine is moderately resistant. These are normally succeeded by basswood, fir and black ash. White pine invades clay-loam sites. Paper birch likes mineral soil and plenty of sun.

Red pine (Pinus resinosa) seems to follow fire sometimes on sandy soil. Opinions differ on whether burning favors this tree. It is itself quite resistant to fire, having moderately high crowns, deep roots and growing in open stands.

Aspen (Populus spp.) is a well-known fire cover. Vegetative sprouting occurs in the first year following fire, and germination of seeds is very vigorous two or three years after a fire. Aspen is easily killed, due to thin bark. Stands are persistent, fairly dense, and hard to replace by other trees.

Black spruce (Picea mariana) is easily killed by fire but re-establishes quickly. As with jack pine, cones open due to heat. Fire also inhibits competition from cedars and tamarack.

White spruce (Picea glauca) is also highly susceptible and sometimes slow to return after fire. Heat destroys seed in the cones and reseeding requires wind or other mechanisms. Spring and early summer fires are the worst; later fires seem to be less serious and reproduction may be fairly rapid.

Longleaf pine (Pinus palustris) is exceptionally fire-resistant and fire can be used deliberately to favor this species. It has thick bark, very deep roots, high, open crowns and grows in very open stands. Other generally resistant species are pitch pine (Pinus rigida), pond pine

(Pinus serotina), slash pine (Pinus elliottii), shortleaf pine (Pinus echinata), loblolly pine (Pinus taeda) as well as red pine.

The least resistant eastern species are firs (Abies spp.), cedars (Thuja spp. and Juniper spp.), aspens, spruces, birches, sugar maple (Acer saccharum), and scarlet oak (Quercus coccinea).

Among Western species, the redwood (Sequoia sempervirens) is extremely resistant to fire, as is the Western larch (Larix occidentalis). Ponderosa pine (Pinus ponderosa) and Douglas fir (Pseudotsuga menziessii) are also highly resistant. All have very thick bark and deep roots. The redwood and larch have high crowns, while the ponderosa and larch grow in open, or relatively open, stands.

At the other extreme Alpine fir (Abies lasiocarpa) has very thin bark, grows in dense stands and is highly susceptible. Only slightly more resistant are western red cedar (Thuja plicata), western hemlock (Tsuga heterophylla), Engelmann spruce (Picea engelmanii), and Sitka spruce (Picea sitchensis), due to relatively thin bark and dense growths.

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CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

In this chapter we shall present, first, a summary of the evaluations given in earlier chapters (II, III, IV)* with respect to specific environmental affects of a thermonuclear attack on the United States. It will survey the possible approaches toward a continuation and extension of the present study. In particular, we shall consider the possible advantages and disadvantages of developing "ecological scenarios."

Section §2 will discuss further the question posed at the outset (Chapter I §1), namely: what constitutes a large attack, from the environmental or ecological standpoint?

The third and final section will discuss other recommendations for further research or for action on the part of OCD, especially in the area of countermeasures. Some priorities based on crude cost-effectiveness considerations will be included.

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*Chapter I consists only of background and factual data, as do the Annexes.

§1 Summary of Evaluations

Chapter II discussed the human "food chain", in a generalized sense, including other necessities such as fiber, drugs and medicines and other products having a biological source. Since the 'Chain' is usually short (one or two links), the chapter could have been entitled "Requirements and Sources of Necessities."

Section §1 discussed nutritional requirements. It was concluded that in a postattack environment Calories (energy) would cause the least potential difficulty. Most minerals would probably pose no serious problem, provided certain measures are taken beforehand to ensure supplies of inorganic calcium and phosphorous, much of which normally comes from milk or dairy products. The fat-soluble vitamins (A, D, E, K) and essential fatty acids (mainly linoleic acid) also do not seem likely to be a bottleneck, again provided adequate advance preparations have been made. The most critical problems would probably be to supply certain of the water-soluble vitamins (B-complex, C, P) and essential amino-acids (protein). In particular, attention was drawn to three points:

a.) The role of intestinal bacteria in supplying B-vitamins, their dependence on lactose and P-amino benzoic acid (PABA), and their susceptibility to anti-biotics and sulfa-drugs was described. The connection between B-vitamin shortage and enteric diseases (typhoid, dysentery, etc. usually treated by sulfas and anti-biotics) common in crowded conditions with bad sanitation was emphasized. All of these were related to probable postattack conditions.

b.) The role of vitamin C in promoting and maintaining the disease-fighting mechanisms of the body was pointed out, especially in the context

of widespread radiation sickness, together with its extreme fragility (bad storage characteristics) and our present-day dependence on citrus fruits and green vegetables for much of the supply.

c.) The distinction between essential and inessential amino-acids was drawn. Evidence suggests that the sulfur-containing amino-acids, methionine and cystine, are likely to be hardest to supply in postattack diets.

Effective measures to alleviate these potential problems will require careful advance planning and may not be altogether successful.

Section §2 discussed the distribution of various essential crops. A comparison of the attack maps and the crop maps points up several salient facts. Most important, any large scale "mixed" attack, such as the two shown on Maps II-1, 2 will have very uneven consequences, agriculturally speaking. A number of crops are geographically vulnerable, particularly citrus fruits (lemons most of all), vegetables, and potatos. Cereal grains, being widespread, are much less vulnerable.

An unfortunate coincidence is apparent: most of the good farming areas west of the great plains -- particularly the irrigated regions -- have been chosen for SAC and missile bases. This is disturbing in view of the large expanse of empty desert, scrubby brushland and barren mountains available in northern Arizona, Nevada, and Utah.

Section §3 discussed possibilities of artificial ecosystems to produce essential biological products. In most cases, it was pointed out, these artificial ecosystems (e.g. to produce algae as supplementary food sources, or to produce various drugs with biological sources) require considerable industrial capacity, which might not survive an attack. Apart from stock-piling medical supplies, it may be desireable for chemical and drug

manufacturing concerns to consider further decentralization of facilities in planning their future expansion.

Chapter III discussed pests and diseases of humans, of domestic animals, and of crop plants, together with relevant ecological factors.

Section §1 discussed diseases of humans and domestic animals together due to their similarities. Diseases due to nematodes were neglected, as being unlikely to increase in importance in consequence of a nuclear attack. Differences in modes of treatment for man and animals were stressed, particularly the possibility (and desirability) of slaughtering sick animals. Differences in modes of propagation, due to isolation of herds from one another, etc. were also pointed out.

As regards humans, the primary danger point seems most likely to be hospitals themselves, crowded with victims of radiation sickness (which means low disease-resistance), short of drugs, vaccines and blood-plasma, and already known to be permanent foci of infection of many highly resistant disease organisms (Staphylococci, Streptococci, etc.). One latent typhoid carrier, for example, in such circumstances could produce an explosive epidemic.

Crowded community fallout shelters (e.g. converted schools, courthouses, etc.) could be dangerous. It is likely that many people would abandon their homes and continue to live in the shelters for long periods to avoid any unnecessary exposure to residual radiation. Bad sanitation might result in polluted water, resulting in dysentery, typhoid and other enteric infections. Crowded habitations are also breeding grounds for lice, flies, and often rats. Typhus often breaks out in such circumstances and plague is a possibility (though neither is endemic in the US).

Absence of nationwide public health controls could also result in malaria, yellow-fever, smallpox, cholera or other epidemic diseases.

As regards animals, continued isolation of herds, and slaughtering of the sick (if possible!) will probably keep disease from spreading. In a postattack environment it might be difficult to dispose of carcasses safely, however.

Section §2 discussed plant diseases. It was emphasized that treatment is virtually never economic (except for trees), so that efforts are directed towards controlling spread, and developing inherited resistance. In a postattack environment the active development of hybrid strains will for a time certainly be inhibited or halted. The fact that background radiation is likely to increase the rate of mutation of pathogens can only increase the difficulty.

To the extent that active farming continues, cultural controls will still be feasible and should be fairly effective. Insecticides may be in short supply but probably not completely unavailable. The unknown factors center on secondary effects:

(i) Do insects (which spread disease) multiply vastly or not?

(ii) What happens to the weather?

The answer in both cases is equivocal.

Section §3 discussed insects specifically, especially in terms of the question asked above. Some evidence was presented to the effect that insects whose larvae live out in the open may not be able to benefit immediately, in a postattack situation, by the (presumed) decimation in the ranks of their principal vertebrate enemies. Thus caterpillars and aphids seem unlikely to multiply disastrously, at least in the first or second year. On the other hand bark-beetles, Japanese beetles, grasshoppers and crickets whose larval stage is more protected from β-radiation are quite likely to do so. (These

insects are among the most likely to undergo population explosions in favorable circumstances anyhow.) We note, particularly, that predation is not demonstrably an important factor in governing the population of any of the latter insects. On the other hand they are all characterized by relatively long life cycles (usually one generation per year, except in exceptionally favorable climates). Population buildup is consequently slower than for most of the crop pests and is more strongly influenced by the the climate, especially the severity of the winter, and the availability of food.

It appears, therefore, that the fast-breeding crop destroyers are likely to be severely decimated themselves by a heavy deposition of fallout. On the other hand, many insects whose habits give a considerable degree of protection from radiation, are fairly slow breeders whose population dynamics are relatively independent of predator pressures, but influenced by climate and food supply.

Conclusions such as the above are necessarily hazy to a degree, and subject to a number of assumptions which are only justified by a lack of specific data, particularly on radiosensitivities and radio-nuclide cycling.

Section §4 is a discussion of the higher vertebrates, particularly rodents and insectivores (especially birds). The main points brought out were:

(i) An attack in winter would find many of the small, fast-reproducing vertebrates protected in holes or crannies (and some birds absent). They would be able to continue to exert pressure on the insect community the following spring, almost as usual.

(ii) In fact an argument was presented to the effect that the most likely consequence would be an outbreak of rodents, due to the disappearance of (many of) their predators.

The distinction between 'winter' and 'summer' is not significant everywhere in the U.S., but it is certainly important in the northeast and midwest (the most populous areas) and in the northern great plains, as well as all mountainous regions.

Section §5 is a brief discussion of "weeds" as pests. No useful conclusions could be reached, except the general statement that the balance between useful and useless plants would probably be upset (to some extent) in favor of the latter, following a thermonuclear attack. This would probably occur independently of secondary effects, simply as a consequence of relaxation of pressure by farmers.

Chapter IV discussed abiotic factors in the environment, particularly weather and watershed problems (e.g. erosion). In section §1 possible interactions between a nuclear attack and weather conditions were surveyed. Evaluations could not be attempted, but several possibilities were outlined. The most plausible direct result seems to be an over-all cooling effect as a result of large amounts of semi-opaque dust being released into the stratosphere. Consequences are very hard to predict. The most likely indirect influence on weather and climate would be through destruction of forests. Serious disagreement exists among meteorologists as to the potential importance of such destruction.

Section §2 focussed attention on water and soil conservation. Again the question was what the effect of the destruction of forests might be. In this case the evidence, though meagre, seems to point to two conclusions:

1. Runoff and ground water would increase, if anything.

2. Erosion might take place, especially if hot fires destroyed the organic material protecting the soil on steep slopes, and most particularly if heat absorption by a layer of soot and fallout on the surface of winter snow

resulted in abnormally fast melting. However the over-all cooling previously mentioned could counteract this somewhat.

An accelerated thaw could result in extremely serious floods, probably unprecedented in the normal weather cycle, which could produce very severe erosion on lower slopes, and tremendous silting in river valleys.

Annex C contains background on water-storage capacities in several western states.

Section §3 reviewed the various roles of forests in the ecosystem, many of which were touched upon in other parts of the report. Mechanisms whereby forests could be damaged or destroyed as a result of an attack were summarized, with special attention to the possible effects of fires (not discussed elsewhere in this report). It seems likely that a combination of insects, insect-borne disease, and fallout would be the worst hazard to the forests, with fires being of lesser importance. Annex E includes background information on ecological aftereffects of fires.

Possible Extensions. There are two possible approaches for future efforts: analytic and synthetic.

The analytic approach to a continuation of the present study would include both general and specific objectives. The general aim would be to continue to search and collect the scientific literature for research bearing on radio-ecology, both past and current. The specific aim would be to narrow the focus of attention while increasing the "magnification."

To take one example: having identified grasshoppers, Japanese beetles and bark beetles as likely to escape radiation damage, their life histories, habits, climatic preferences, etc., should be examined in more detail (always from the point of view of the postattack environment).

The analytic approach would proceed similarly with the other elements which have already been labelled as "most likely to be critical."

At the same time the arguments by which the more critical elements were tentatively identified should be reviewed and tested. In some instances unsuspected subtleties will appear which may change the conclusions. Still deeper study would be called for in these cases.

The synthetic approach would be an explicit effort to picture the situation which would result from a thermonuclear attack, in terms of its impact on some selected (typical) locality. Since analysis cannot do this job completely, an exercise of literary imagination might fill some of the gaps and make the picture (or "scenario") coherent.

The value of the result depends on the extent to which the many disparate elements have been successfully fitted together, correctly taking account of their known mutual interactions. Information about life-cycles, natality, or climatic sensitivities may not be especially useful in such an endeavor, except that the end result must be consistent with the available data. Information such as the fact that quail populations and cotton-rat populations tend to increase and decrease synchronously (at least in north Texas) is equally or more likely to be helpful.

In synthesizing ecological scenarios one requires, above all, information about ecological events of great magnitude which have occurred in the past. The rat-quail outbreak alluded to above is a typical example out of hundreds in the literature.

Two such events are recorded in detail as Appendices to this report. Appendix II describes an outbreak of bark-beetles which destroyed 500,000 acres of spruce trees. Appendix III describes the eruption of Krakatau in 1883 which lifted several cubic miles of volcanic debris into the sky. Some comments are included indicating some of the implications of these events for a postattack environment.

2. "Large" and "Small" Attacks

To relate military-strategic parameters describing the size of an attack to environmental consequences some sort of theory is required. At present we can offer only some rather hazy notions which may stimulate further thought on the subject.

In words: a big war, ecologically-speaking, would be one in which the balance of nature were severely disturbed. The size of the attack would then be functionally related to the severity of the disturbance.

Even a cursory glance at the problem in these terms reveals one relevant fact, namely, that the functional relationship is non-linear. That is to say, a small disturbance is likely to be self-compensating, whereas a large (enough) one will not be. (To take an extreme case: a sufficiently great disturbance could result in the permanent denudation of a whole continent.) This introduces the notion of unstable equilibrium, and suggests a possible ecological criterion of a "large" attack: one which is large enough so that disturbances do not result in self-compensating corrections, but lead to some new (unstable) equilibrium.

Simple examples of this sort of situation are well-known. It has been repeatedly demonstrated that loss of vegetation (say, due to logging or fire) from a hillside will cause erosion. If the damage is stopped early enough, the vegetation will return fairly rapidly. But if the vegetation is inhibited for a sufficiently long period erosion proceeds to the point of no return, all the top soil is lost and the area will no longer support the same type of plant life. Several copper smelting areas in the U.S. and Canada have experienced such a permanent change. Possibly the once-wooded and fertile areas of North Africa were turned into desert by a similar long-term mechanism (overgrazing).

The point-of-no-return for an ecosystem, thus loosely defined, would determine how many Curies or MT's could be tolerated. Ecological systems certainly vary widely in their ability to recover. The radiosensitivity of the various species is one factor, and the details of the mutual interactions are another one. We can say very little of a general nature which would throw light on the problem.

One possible generalization--and a dubious one at that--: the more complex an ecosystem, the more self-compensating mechanisms there may be, and the better its ability to return to something like the original equilibrium. This is based on the observation that complex ecosystems (such as tropical jungles or temperate forests) suffer fewer wild oscillations than simple systems (e.g. arctic regions). Unfortunately we do not feel justified at present in attempting to state a clearer or more explicit connection between attack parameters and ecological consequences.

§3. Recommendations

A possible dichotomy would be to divide the recommendations into two categories, (1) study programs and (2) action programs. Admittedly the division seems to be somewhat artificial, since all study programs (at least within OCD) should be directed in some sense toward determining future actions. Moreover it would be unreasonable for OCD to take specific actions on the basis of recommendations resulting from a preliminary study without at least extending the investigation to cover the practical details (how? where? how much? etc.). Thus each implies the other. Nevertheless recommendations will be clearly either "action-oriented" or "study-oriented."

One other distinction seems to be useful, and that arises in defining objectives. One set of measures can be designed (in view of our previous evaluations) to maximize chances of survival. Another may be designated to maximize the rate (or probability) of recovery. We have three categories:

1. An action-oriented program to maximize survival chances by stockpiling certain dietary and medical items in central locations or community shelters around the country, would consider:

   a) Vitamin C --A one year supply for the whole population, assuming 50 mg. per person per day, would require a stockpile of 5,000 tons of the pure vitamin. It should be noted that this is equivalent to roughly 18 months of normal production.*

   b) Mineral tablets containing calcium, phosphorus, iron, iodine

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*U.S. Tariff Commission, Synthetic Organic Chemicals, U.S. Production & Sales, 1961, Washington, D.C. (1962).

and salt. (Again, production problems are by no means trivial and normal production might have to be multiplied manyfold.)

c) Fish liver-oils for Vitamins A, D, E, linoleic acid, etc. (Commercial fisheries probably produce enough to build up such a stockpile in a reasonable time. Animal liver oils, and vegetable seed oils (peanut, soybean, cottonseed) could be added. Methods of inhibiting oxydation should be tested, e.g. vacuum storage.)

d) Lactose, PABA and vitamin B-complex tablets could be stockpiled <u>with</u> all sulfa-drugs in reasonable quantities.

e) All community fallout shelters likely to be inhabited for extended periods could be provided with a number of miscellaneous items, including:

  (i) ultraviolet lamps (where there is power available)

  (ii) warfarin (rat poison)

  (iii) insecticide (mainly powders for external application)

  (iv) water decontamination supplies (e.g. chlorine pills in calibrated amounts, etc.) or rechargeable ion-exchange water purification equipment.

f) At strategic locations there could be stockpiles of the more critical medical supplies, especially

  (i) tetracyclines, chloramphenicol and erythromycin

  (ii) plague, cholera, typhoid & paratyphoid, diphtheria, smallpox, polio and pertussis vaccines (to be used primarily to protect medical workers).

(iii) blood plasma and whole-blood

(iv) ACTH, cortisone and other steroids

2. An action-oriented stockpiling program to maximize (agricultural) recovery chances by stockpiling essential biological elements would consider:

a) Crop seeds of pure strains of all major crops. Should be kept dry, refrigerated (if possible), purified, fumigated, etc.

b) Animal sperm, especially for dairy stock

c) Live female animals and birds, particularly insectivores capable of rapid reproduction, e.g. shrews, woodpeckers.

d) Biological materials such as nitrogen bacteria innoculant for legumes, bacterial and viral cultures used in controlling insects (e.g. Bacillus Thuringiensis)*

e) Live insects or fertilized (refrigerated) insect eggs of beneficial species likely to be needed, e.g. lady-beetles, honeybees, etc.

The above stocks could be used to establish breeding farms or nurseries when conditions permit. These measures are in addition to storing insecticides, fungicides, herbicides, tractor fuel, etc., commonly recommended.

3. Several research-oriented programs. The list of desirable research projects is almost endless so we restrict attention to examples arising directly out of the present study:

a) Radio-nuclide cycling should be investigated in various predator-prey situations, particularly among insects and insectivores. Parasites, predators or insectivores of special interest

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*This and several other biological pesticides are now manufactured commercially by at least three companies in the U.S. and one in France (New York Times, April 12, 1963).

might be:

parasitic wasps and flies

lady-beetles and lace-wings

spiders

dragonflies

praying mantids

shrews and voles

various insectivorous birds

Experiments under laboratory conditions with labelled nuclides would be easy, inexpensive and very informative. This would be ideal for research contracts to universities.

b) Fallout simulation, either in a laboratory ecosystem (e.g. a greenhouse) or in conjunction with atomic tests could be attempted. The former would be preferable for many reasons, even if the simulation of fallout proved difficult. Weather conditions would be predictable, measurements would be easy to make, there would be no problem of allowing for movement of species into or out of a test site, the amount of radio-active material present would be known accurately rather than conjectured from scattered instrument readings. Moreover test-site programs are underway already in Nevada (Brigham Young University) and in the Pacific.

Even if the testing were carried out at the convenience of the ecological researchers (which they are not and may not be in the foreseeable future) so that preparations were complete,

"before" and "after" studies feasible, etc., most of the difficulties mentioned still apply. In addition, such experiments are perforce limited to ecosystems of little or no practical importance, though admittedly general principles discovered from such experiments might be applicable in other ecosystems.

The investigation should concentrate on studying synergistic effects, relative importance of γ-radiation, β-radiation and α-radiation, lethal doses for insects and animals with different life cycles, and so forth. The effect of the time rate of decay of the fallout should also be noted (this could be investigated to some extent by conventional techniques). Insects, small animals, and possibly even birds, could be brought into the greenhouse ecosystems.

We therefore recommend consideration of laboratory experiments on "greenhouse" ecosystems. Such a program would be time-consuming and moderately expensive, but may be well worth the cost. A large number of studies have been advocated* which would be of great importance to the study of a postattack environment, but are also of more general ecological interest. More studies of predator-prey-plant relationships, soil erosion, consequences of "hot" forest fires, dynamics of population explosions, the connection between mutations and evolution (e.g. new pathogens) are all needed. Such investigations would be carried out anyway

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*See the Summary of Proceedings at the Conference on Ecological Considerations held at the Hudson Institute, July 30-31, 1962.

in the normal course of development of biology and particularly ecology. We see no immediate prospect of OCD being in a position to actually subsidize any substantial number of such projects, if only because most are not "clearly" within the civil defense area. Thus no single one is of high priority. Yet the continued or even accelerated advancement of the field, as a whole, is definitely very important for OCD.

We recommend, therefore, that a degree of professional competence in this area should be retained (or built-up, to the extent that it does not presently exist) by OCD. This would imply familiarity with current ecological literature, and with the status of various ongoing projects funded by other agencies (mainly AEC). It would also involve further analytical work correlating existing statistical data, surveys of past ecological events, and evaluations of ecological "models" etc. As well as the development of new approaches such as "scenarios."

To summarize, we propose that careful consideration be given (e.g. that "engineering-type" studies be initiated) on two different stockpiling programs, (1) for survival capabilities and (2) for agricultural recovery capabilities.

We also recommend specific experimental (laboratory-type) programs of special importance to OCD, (a) on radio-nuclide cycling in predator-prey food chains, particularly involving insects and insectivores, and (b) on simulation of fallout in closed (greenhouse) ecosystems under controlled conditions. Beyond this we feel that OCD should maintain continuing competence in, and contact with, current research on bio-ecological problems.

APPENDIX I

(Abstract from Summary of Progress from Sept. 1, 1962 to Dec. 15, 1962)

Survey of Twenty-seven Research Projects Currently in Progress

As part of the preliminary investigations under this contract we compiled a list of 27 current research contracts which appeared to be in some way related to ecology in a post-attack environment. Of these, three were from the Department of Health, Education and Welfare, one was at Walter Reed Hospital, and the remainder financed by the AEC. The vast majority of ecological studies are only of marginal interest.

For example, only one study is specifically related to cycling of radionuclides in plants of agricultural importance; we have not yet learned any details of this program.

Three studies are concerned with radiosensitivities of forest trees and seeds.

Two studies are concerned with effects of radiation on animal populations under experimental conditions. One of these studies is restricted to lizards. The other is concerned with a variety of small vertebrates.

Two studies are concerned with the ecological after-effects of nuclear tests. One refers to the biotic community of coral atolls in the central Pacific; the other to a desert community in Nevada. A third promising study was to have been done in connection with project "Chariot" on the north west coast of Alaska, but this project has been shelved, at least temporarily.

The remaining studies in the group are concerned with such things as the somatic effects of fallout from nuclear testing, the mechanisms of radio-nuclide cycling in plants generally, or in aquatic communities. Several studies are specifically ecological, but are limited to the ecological effects of very low level contamination such as is to be found in the vicinity of AEC installations.

The most important observation which emerges from the still incomplete survey is that a number of the most important subjects (from a postattack point of view) have been either totally or comparatively neglected. For example:

i) No extensive "serious" studies appear to have been done on radiosensitivities of most important agricultural plants. Only a small amount has been done on cycling of radio-nuclides in these plants. At present one is left with little besides Sparrow's theoretical predictions (valuable as they may be) in regard to the sensitivities of these important species. (See Chapter I 3.)

ii) No studies appear to have been done at all on the effect of radiation from fallout on insects. Laboratory experiments have been done largely with x-rays, under conditions far from natural. The effects of β-particles on insects (which would often theoretically be much more important than x-rays) have been virtually ignored. Moreover those species which have been studied extensively in the laboratory are by and large not of greatest economic concern.* From the point of view of a postattack environment one would like to know about the effects of fallout

*In a postattack environment--though admittedly pests of stored grain (which have been studied) are not unimportant.

on bees, ants, mosquitoes, grasshoppers, and locusts, and various widespread agricultural pests such as weevils, borers, and beetles.

iii) One would like to see much more attention to grasslands and croplands, and their indigenous populations. Such ecological work as is being done today is remarkably concentrated in areas of comparatively little importance for nuclear war problems--such as deserts, ponds, and streams.

iv) No studies at all seem to have been devoted to possible epidemiological consequences of nuclear war.

v) Finally, one must emphasize as a general remark, the obvious fact that the majority of existing projects have been undertaken with reference to very low level contamination (arising from either fallout or waste-disposal). It is puzzling that both researchers and sponsoring agencies have thought it worthwhile to undertake a number of investigations having the specific orientation of "classical" ecology with applications restricted to the extreme low-level intensity case where effects, if any, are likely to be detectable only statistically over long periods. In the interesting (scientifically) and more critical (post-war survival) case of high-level radioactivity there is virtually nothing being done outside of Brookhaven and Emory University.